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TECHNICAL CHEMISTS' HANDBOOK

TECHNICAL CHEMISTS' HANDBOOK

TABLES AND METHODS OF ANALYSIS FOR
MANUFACTURERS OF INORGANIC CHEMICAL
PRODUCTS

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THIRD EDITION REVISED

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PREFACE

THE aim of *The Technical Chemists' Handbook* is to effect, as far as possible, the task of establishing uniformity among practical chemists, buyers and sellers, and analysts, in regard to both the numerical data employed in their work and the analytical methods used for the control of processes, and for the testing of the resulting products.

In the preparation of this new edition, all the analytical factors have been recalculated on the basis of the atomic weights published by the International Committee for 1916. This has involved in exceedingly numerous cases changes of the data contained in the last edition, some of them of importance even for merely practical purposes. The tables of specific gravities and other tables have been selected from among the most recent and reliable determinations.

In regard to the analytical methods, they are again chosen as before, on the principle that, as a rule, only *one* method should be given for each analytical operation, as well as for the preparation of standard solutions and for sampling the materials, in order to avoid discrepancies such as might arise should two or more methods be described. The method chosen should always, of course, be that which permits the greatest degree of accuracy possible that can be attained in a well-appointed works laboratory by a properly trained chemist. In cases where there is a choice between equally accurate methods, that occupying least time or least apparatus, or which is already widely known and employed, has been preferred. Many new methods have accordingly had to be omitted, but in all cases such omissions have

been justified by means of a careful examination of the relative merits of the processes under consideration, and only such methods as were found thoroughly reliable have been included. Also, a considerable number of tables of specific gravities of solutions not previously worked out, or which were unsatisfactory, have been very carefully checked and extended.

When necessary, reference is made to the more complete treatment of the subject-matter in my larger treatise, published with the co-operation of Dr Charles A. Keane, under the title *Technical Methods of Chemical Analysis*, in three volumes of two parts each, in 1908-1914. This treatise is referred to in the text as *Tech. Meth.*

THE AUTHOR.

ZÜRICH, Jan. 1916.

PREFACE TO THE THIRD EDITION

IN preparing a new edition of this book, I have kept to the general lines explained by Dr Lunge in his preface to the last edition. Revision has necessarily involved many minor alterations, but there is no change in the general scheme of the book.

In a book of this kind, accuracy in figures is obviously of the greatest importance, and so many errors were discovered that so far as possible all figures in the book have been recalculated.

I desire to thank many friends for information and assistance. One of them, Mr Allin Cottrell, kindly rewrote the section on Nitric Acid and Nitrates shortly before his untimely death.

Mr J. W. Parkes has my thanks for not only revising the section on Sulphuric Acid, but also for sending me a list of errors in the previous edition which was very helpful to me.

I desire also to thank specially Dr J. Knox for reading the proofs and Miss Deakin for proof-reading and a great deal of laborious checking of figures.

ALEX. C. CUMMING.

LIVERPOOL, *October* 1929.

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GENERAL TABLES

N O T E

ALL *temperatures* are given in degrees Centigrade, unless otherwise stated.

The *atomic weights* are those adopted by the International Committee on Atomic Weights as given in Table No. 1 referred to Oxygen = 16.

TABLE 1.—INTERNATIONAL ATOMIC WEIGHTS

According to the Table issued by the International Committee
on Atomic Weights. (Revised to 1929.)

| | | | | | |
|----------------------|----|--------|------------------------|----|--------|
| Aluminium | Al | 27·1 | Molybdenum | Mo | 96·0 |
| Antimony | Sb | 120·2 | Neodymium | Nd | 144·3 |
| Argon | A | 39·9 | Neon | Ne | 20·2 |
| Arsenic | As | 74·96 | Nickel | Ni | 58·68 |
| Barium | Ba | 137·37 | Niton | Nt | 222·4 |
| Bismuth | Bi | 208·0 | Nitrogen | N | 14·008 |
| Boron | B | 10·9 | Osmium | Os | 190·9 |
| Bromine | Br | 79·92 | Oxygen | O | 16·000 |
| Cadmium | Cd | 112·40 | Palladium | Pd | 106·7 |
| Cæsium | Cs | 132·81 | Phosphorus | P | 31·04 |
| Calcium | Ca | 40·07 | Platinum | Pt | 195·2 |
| Carbon | C | 12·005 | Potassium | K | 39·10 |
| Cerium | Ce | 140·25 | Praseodymium | Pr | 140·9 |
| Chlorine | Cl | 35·46 | Radium | Ra | 226·0 |
| Chromium | Cr | 52·0 | Rhodium | Rh | 102·9 |
| Cobalt | Co | 58·97 | Rubidium | Rb | 85·45 |
| Columbi | Cb | 93·1 | Ruthenium | Ru | 101·7 |
| Copper | Cu | 63·57 | Samarium | Sm | 150·4 |
| Dysprosium | Dy | 162·5 | Scandium | Sc | 45·1 |
| Erbium | Er | 167·7 | Selenium | Se | 79·2 |
| Europium | Eu | 152·0 | Silicon | Si | 28·3 |
| Fluorine | F | 19·0 | Silver | Ag | 107·88 |
| Gadolinium | Gd | 157·3 | Sodium | Na | 23·00 |
| Gallium | Ga | 70·1 | Strontium | Sr | 87·63 |
| Germanium | Ge | 72·5 | Sulphur | S | 32·06 |
| Glucinum | Gl | 9·1 | Tantalum | Ta | 181·5 |
| Gold | Au | 197·2 | Tellurium | Te | 127·5 |
| Helium | He | 4·00 | Terbium | Tb | 159·2 |
| Holmium | Ho | 163·5 | Thallium | Tl | 204·0 |
| Hydrogen | H | 1·008 | Thorium | Th | 232·15 |
| Indium | In | 114·8 | Thulium | Tu | 168·5 |
| Iodine | I | 126·92 | Tin | Sn | 118·7 |
| Iridium | Ir | 193·1 | Titanium | Ti | 48·1 |
| Iron | Fe | 55·84 | Tungsten | W | 184·0 |
| Krypton | Kr | 82·92 | Uranium | U | 238·2 |
| Lanthanum | La | 139·0 | Vanadium | V | 51·0 |
| Lead | Pb | 207·20 | Xenon | X | 130·2 |
| Lithium | Li | 6·94 | Ytterbium | Yb | 173·5 |
| Lutecium | Lu | 175·00 | Yttrium | Y | 88·33 |
| Magnesium | Mg | 24·32 | Zinc | Zn | 65·37 |
| Manganese | Mn | 54·93 | Zirconium | Zr | 90·6 |
| Mercury | Hg | 200·6 | | | |

TABLE 2.—WEIGHTS AND MEASURES OF DIFFERENT COUNTRIES.

1. **Metric System** (compulsory in France, Germany, Austria, the Netherlands, Belgium, Luxemburg, Switzerland, Italy, Greece, Turkey, Roumania, Spain, Portugal, and most of the South American Republics; optional in Great Britain, the United States, and Russia).

- 1 metre (m.) = 443·296 Paris lignes = 3·280899 English feet = 3·18620 Prussian feet = 1·00000301 mètres des archives.
 1 kilometre (km.) = 10 hectometres (hm.) = 0·6214 English mile = 0·1328 Prussian mile = 0·9375 Russian verst = 0·5390 nautical mile = 0·1347 geographical mile (15 to 1 degree of longitude).
 1 lieue (France) = 1 myriametre = 10 km.
 1 German mile = $7\frac{1}{2}$ km. = 0·996 Prussian mile = 4·66 English miles.
 1 hectare (ha.) = 100 ares (a.) = 10,000 sq.m. = 0·01 sq.km. = 2·471 English acres.
 1 litre (l.) = 0·001 cb.m. = 1000 c.cm. = 0·2201 gallon.
 1 hectolitre (hl.) = 0·1 cb.m. = 100 l. = 22·01 gallons.
 1 kilogram (kg.) = 1000 g. = weight of 1 litre of water at +4° C. = 2 German and Swiss pounds (zollpfund) = 0·999999842 kilogram prototype = 2·2046 pounds avoirdupois = 1·7857 Austrian pounds = 2·3511 Swedish pounds = 2·4419 Russian pounds.
 1 gram (g.) = 15·432 grains (English).
 1 quintal = 100 kg. = 196·84 lbs. avoirdupois = 1 cwt. 3 qrs. 0·84 lb.
 1 metrical ton = 1000 kg. = 0·9842 English ton = 1·1023 American short tons (at 2000 lbs.).

2. **Great Britain and Ireland.**

- 1 foot = 0·3047943 m.
 1 inch = 25·3995 mm.
 1 yard = 3 feet = 0·9143835 m.
 1 fathom = 2 yards = 1·829 m.
 1 rod (pole, perch) = $5\frac{1}{2}$ yards = 5·029109 m.
 1 chain = 22 yards. 80 chains = 1 mile.
 1 statute mile = 8 furlongs = 320 poles = 1760 yards = 5280 feet = 1·6093 kilometre (km.).
 1 nautical mile = $\frac{1}{60}$ th degree (at the equator). 6082·66 feet = 1854·96 m.
 1 acre = 4 roods = 160 poles = 0·40467 ha. = 43560 square feet = 4047 square metres.
 1 square mile = 640 acres = 258·989 ha.
 1 gallon = 4 quarts = 8 pints = 277·274 cubic inches = 4·536 litres.
 1 cubic foot = 1728 cubic inches = 28·3153 l.
 1 cubic inch = 16·3862 c.cm.
 1 quarter = 8 bushels = 32 pecks = 64 gallons = 2·903 hl.
 1 bushel = 8 gallons = 0·3628 hl.

TABLE 2—*Continued.*

- 1 fluid ounce = $\frac{1}{2}$ th pint = 28·35 c.cm.
 1 pound avoirdupois (lb.) = 16 ounces (oz.) = 7000 grains = 0·4535926 kg.
 1 ounce avoirdupois = 437½ grains = 28·35 g.
 1 gallon = 10 lbs. water = 70,000 grains = 4·535926 kg. water.
 1 hundredweight (cwt.) = 4 quarters (qr.) = 8 stones = 112 lbs. = 50·8024 kg.
 1 ton = 20 cwt. = 2240 lbs. = 1016·648 kg.

Apothecaries' Weight.

- 1 pound troy = 12 ounces troy = 96 drams = 288 scruples = 5760 grains = 373·24195 g.
 1 ounce troy = 8 drams = 24 scruples = 480 grains = 31·1035 g.
 1 ounce troy (for gold and precious stones) = 20 pennyweight (dwt.) = 480 grains = 31·1035 g.
 1 pennyweight (dwt.) = 1·552 g.
 1 grain (common to avoirdupois and troy weight) = 0·06479895 g.

3. Austria (old measures and weights, now abolished for the metric system).

- 1 foot = 0·316102 m., at 12 inches of 12 lines each.
 3 ruthen = 5 klafter = 30 feet = 360 zoll.
 1 meile = 4000 klafter = 7586·455 m.
 1 maass = 1·415 l.
 1 eimer = 40 maass = 160 seidel.
 1 metze = 61·4995 l.
 1 Wiener pfund = 560·012 g.
 1 centner = 5 stein = 100 pfund = 3200 loth.

4. Denmark and Norway employ, as unit of measure, the Prussian foot, as unit of weight the units of the metrical system, viz., kilos, etc.**5. Prussia** (old system, now abolished for the metric system).

- 1 foot (Rhenish foot) = 12 zoll (inches) = 144 linien = 0·313853 m.
 1 ruthe = 12 fuss = 3·76624 m.
 1 lachter (fathom) = 80 zoll = 2·09326 m.
 1 meile = 24,000 fuss = 7532·5 m.
 1 morgen = 180 square ruthen = 0·2553 ha.
 1 quart = 64 cubic inches = $\frac{1}{2}$ cubic foot = 1·14503 l.
 1 scheffel = 16 Metzen = 48 quarts = 0·54961 hl.
 1 tonne = 4 scheffel = 2·19846 hl.
 1 klafter = 108 cubic fuss = 3·3389 cb.m.
 1 schachtruthe = 144 cubic fuss = 4·4519 cb.m.
 1 pfund = 80 loth = 300 quentchen = 500 g.
 1 centner = 100 pfund = 50 kg. (Formerly 1 pfund = 32 loth = 467·711 g.; 1 centner = 110 pfund.)

TABLE 2—Continued.

6. Russia.

- 1 foot = 1 English foot.
 1 sashehn = 7 feet = 3 arshin = 12 tchetvert = 48 vershok = 2·13357 m.
 1 verst = 500 sashehn = 1066·78 m.
 1 dessatine = 2400 square sashehns = 10925 m.
 1 vedro = 10 krushky (stoof) = 12·299 l.
 1 tchetvert = 1 osmini = 4 payok = 8 tchetverik = 209·9 l.
 1 pound = 32 loth = 96 solotnik = 9216 doli = 0·9028 Eng. lb.
 = 409·531 g.
 1 berkovets = 10 pud = 400 pounds = 163·81 kg.
 1 pud = 40 pounds = 36·112 Eng. lb. = 16·3805 kg.

7. Sweden.

- 1 foot = 10 Zoll (inches) = 100 lines = 0.97408 Eng. foot = 0.296901 m.
 1 fann (fathom) = 3 alnar (ells) = 6 feet = 5.58445 Eng. feet
 = 1.7814 m.
 1 mile = 6000 fathoms = 6.6417 Eng. statute miles = 10.6884 km.
 1 kanne = 100 cubic inches = 0.57694 Eng. gallon = 2.617 l.
 1 skålpund = 100 korn (at 100 art) = 0.9378 Eng. lb. = 425.3395 g.
 1 centner = 100 skålpund.
 1 skipsbund = 20 liesbund = 400 skålpund.

8. Switzerland. Metrical measure and weight. The following are sometimes still employed :—

- 1 fuss = 0.3000 m. = 0.9843 Eng. foot.
 1 juchart = 36 are = 0.88956 Eng. acre.
 1 maass = 1.51 l.
 1 saum = 100 maass = 151 l.

9. United States. Weights and measures as in Great Britain, but instead of the "long ton" (gross ton) of 2240 lbs., more frequently the "short ton" (net ton) of 2000 lbs. = 907·1852 kg. = 0·89285 long ton, is employed.

The U.S. gallon differs from the British gallon; it is=3.7854 litres. For timber, the measure is the "cord"= $4 \times 4 \times 8$ feet =128 cubic feet=about $2\frac{1}{2}$ cubic metres.

10. **South America** (Bolivia, Chile, Colombia, Ecuador, Guatemala, Honduras, Nicaragua, Peru, San Salvador, Venezuela)—1 quintal = 46.0093 kg.

- | | | |
|---------------------|-------------|-------------|
| Argentina | 1 quintal = | 45·9367 kg. |
| Brazil | 1 .. = | 58·752 .. |
| Paraguay | 1 .. = | 46·008 .. |
| Uruguay | 1 .. = | 45·94 .. |

TABLE 2—*Continued.***Square Feet, Square Metre.**

- 1 square metre (sq.m.) = 10·764 square feet (English and Russian)
 = 10·008 square feet (Austrian) = 10·152 square feet (Prussian
 and Danish) = 11·344 square feet (Swedish).
 1 square foot (English and Russian) = 0·09290 square metre.

Cubic Feet, Cubic Metre.

- 1 cubic metre (cb.m.) = 35·316 cubic feet (English and Russian).
 1 " " " = 31·66 " " (Austrian).
 1 " " " = 32·346 " " (Prussian and Danish).
 1 " " " = 38·209 " " (Swedish).
 1 cubic foot (English and Russian) = 0·028315 cubic metre.

1 Kilogram per Running Metre

- = 0·6719 English pound per running foot.
 = 0·6277 zollpfund per Prussian foot.
 1 English pound per 1 English foot = 1·4882 kg. per running metre.

1 Kilogram per Square Centimetre (for steam pressure)

- 14·223 English pounds per square inch.
 – 13·681 zollpfund per Prussian square inch.
 – 13·878 zollpfund per Austrian square inch.

HORSE-POWER (per second).

| Kg.-m. | Austria. Foot-pounds. | Prussia. Foot-pounds. | England. Foot-pounds. | Sweden. Foot-pounds. | Russia. Foot-pounds. |
|--------|--------------------------|--------------------------|--------------------------|-------------------------|-------------------------|
| 75 | 474·53 | 477·93 | 542·47 | 593·90 | 600·85 |
| 76·041 | 481·11 | 484·56 | 550 | 602·14 | 609·19 |

- 75 kilogram-metres taken as unit,
 550 English foot-pounds taken as unit,
 = 1 Admiralty horse-power per second ;
 or, 33,000 foot-pounds per minute.

TABLE 3.—TABLES FOR CONVERTING ENGLISH TO METRICAL WEIGHTS AND MEASURES, AND VICE VERSA.

Reduction of Metrical Measure to English Measure.

| Metre. Sq.m. Cub.m. | Feet. | Inches. | Square feet. | Square inches. | Cubic feet. | Cubic inches. |
|---------------------------|---------|----------|-----------------|-------------------|----------------|------------------|
| 1 | 3·2809 | 39·3706 | 10·7642 | 1550·05 | 35·3161 | 61026·2 |
| 2 | 6·5618 | 78·7412 | 21·5284 | 3100·09 | 70·6322 | 122052·4 |
| 3 | 9·8427 | 118·1118 | 32·2926 | 4650·13 | 105·9483 | 183078·6 |
| 4 | 13·1235 | 157·4824 | 43·0568 | 6200·18 | 141·2644 | 244104·9 |
| 5 | 16·4044 | 196·8530 | 53·8210 | 7750·23 | 176·5805 | 305131·1 |
| 6 | 19·6853 | 236·2237 | 64·5852 | 9300·27 | 211·8966 | 366157·3 |
| 7 | 22·9662 | 275·5943 | 75·3494 | 10850·31 | 247·2126 | 427183·5 |
| 8 | 26·2471 | 314·9649 | 86·1136 | 12400·36 | 282·5287 | 488209·7 |
| 9 | 29·5280 | 354·3355 | 96·8778 | 13950·40 | 317·8448 | 549235·9 |

English Feet = Metres.

| Ft. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0 | 0·0000 | 0·3048 | 0·6096 | 0·9144 | 1·2192 | 1·5240 | 1·8288 | 2·1336 | 2·4384 | 2·7432 |
| 10 | 8·0479 | 8·8527 | 9·6575 | 10·4623 | 11·2671 | 12·0719 | 12·8767 | 13·6815 | 14·4863 | 15·2911 |
| 20 | 6·0959 | 6·4007 | 6·7055 | 7·0103 | 7·3151 | 7·6199 | 7·9247 | 8·2295 | 8·5343 | 8·8390 |
| 30 | 9·1438 | 9·4486 | 9·7534 | 10·0582 | 10·3630 | 10·6678 | 10·9726 | 11·2774 | 11·5822 | 11·8870 |
| 40 | 12·1917 | 12·4965 | 12·8013 | 13·1061 | 13·4109 | 13·7157 | 14·0205 | 14·3253 | 14·6301 | 14·9349 |
| 50 | 15·2396 | 15·5444 | 15·8492 | 16·1540 | 16·4588 | 16·7636 | 17·0684 | 17·3732 | 17·6780 | 17·9828 |
| 60 | 18·2875 | 18·5923 | 18·8971 | 19·2019 | 19·5067 | 19·8115 | 20·1163 | 20·4211 | 20·7259 | 21·0307 |
| 70 | 21·3354 | 21·6402 | 21·9450 | 22·2498 | 22·5546 | 22·8594 | 23·1642 | 23·4690 | 23·7738 | 24·0786 |
| 80 | 24·3833 | 24·6881 | 24·9929 | 25·2977 | 25·6025 | 25·9073 | 26·2121 | 26·5169 | 26·8217 | 27·1265 |
| 90 | 27·4312 | 27·7360 | 28·0408 | 28·3456 | 28·6504 | 28·9552 | 29·2600 | 29·5648 | 29·8696 | 30·1744 |
| 100 | 30·4791 | 30·7839 | 31·0887 | 31·3935 | 31·6983 | 32·0031 | 32·3079 | 32·6127 | 32·9175 | 33·2223 |
| 110 | 33·5270 | 33·8318 | 34·1366 | 34·4414 | 34·7462 | 35·0510 | 35·3558 | 35·6606 | 35·9654 | 36·2702 |
| 120 | 36·5749 | 36·8797 | 37·1845 | 37·4893 | 37·7941 | 38·0989 | 38·4037 | 38·7085 | 39·0133 | 39·3181 |
| 130 | 39·6228 | 39·9276 | 40·2324 | 40·5372 | 40·8420 | 41·1468 | 41·4516 | 41·7564 | 42·0612 | 42·3660 |
| 140 | 42·6717 | 42·9765 | 43·2813 | 43·5861 | 43·8909 | 44·1957 | 44·5005 | 44·8053 | 45·1101 | 45·4149 |
| 150 | 45·7196 | 46·0244 | 46·3292 | 46·6340 | 46·9388 | 47·2436 | 47·5484 | 47·8532 | 48·1580 | 48·4628 |
| 160 | 48·7715 | 49·0763 | 49·3811 | 49·6859 | 49·9907 | 50·2955 | 50·6003 | 50·9051 | 51·2099 | 51·5147 |
| 170 | 51·8154 | 52·1202 | 52·4250 | 52·7298 | 53·0346 | 53·3394 | 53·6442 | 53·9490 | 54·2538 | 54·5586 |
| 180 | 54·6663 | 54·9711 | 55·2759 | 55·5807 | 55·8855 | 56·1903 | 56·4951 | 56·8000 | 57·1048 | 57·4096 |
| 190 | 57·9112 | 58·2160 | 58·5208 | 58·8256 | 59·1304 | 59·4352 | 59·7400 | 60·0448 | 60·3496 | 60·6544 |

English Inches = Millimetres.

| Inch. | Millimetres. | Inches. | Millimetres. | Inches. | Millimetres. |
|----------------|--------------|---------|--------------|---------|--------------|
| $\frac{1}{16}$ | 0.39 | 1 | 25.4 | 7 | 177.8 |
| $\frac{1}{8}$ | 0.79 | 2 | 50.8 | 8 | 203.2 |
| $\frac{3}{16}$ | 1.59 | 3 | 76.2 | 9 | 228.6 |
| $\frac{1}{4}$ | 3.17 | 4 | 101.6 | 10 | 254.0 |
| $\frac{5}{16}$ | 6.35 | 5 | 127.0 | 11 | 279.4 |
| $\frac{3}{8}$ | 12.70 | 6 | 152.4 | 12 | 304.8 |

English Square Feet = Square Metres.

| Sq. ft. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0 | 0.0000 | 0.0929 | 0.1858 | 0.2787 | 0.3716 | 0.4645 | 0.5574 | 0.6503 | 0.7432 | 0.8361 |
| 10 | 0.9290 | 1.0219 | 1.1148 | 1.2077 | 1.3006 | 1.3935 | 1.4864 | 1.5793 | 1.6722 | 1.7651 |
| 20 | 1.8580 | 1.9509 | 2.0438 | 2.1367 | 2.2296 | 2.3225 | 2.4154 | 2.5083 | 2.6012 | 2.6941 |
| 30 | 2.7870 | 2.8799 | 2.9728 | 3.0657 | 3.1586 | 3.2515 | 3.3444 | 3.4373 | 3.5302 | 3.6231 |
| 40 | 3.7100 | 3.8029 | 3.9018 | 3.9947 | 4.0876 | 4.1805 | 4.2734 | 4.3663 | 4.4592 | 4.5521 |
| 50 | 4.6450 | 4.7379 | 4.8308 | 4.9237 | 5.0166 | 5.1095 | 5.2024 | 5.2953 | 5.3882 | 5.4811 |
| 60 | 5.5740 | 5.6669 | 5.7598 | 5.8527 | 5.9456 | 6.0385 | 6.1314 | 6.2243 | 6.3172 | 6.4101 |
| 70 | 6.5030 | 6.5959 | 6.6888 | 6.7817 | 6.8746 | 6.9675 | 7.0604 | 7.1533 | 7.2462 | 7.3391 |
| 80 | 7.4320 | 7.5249 | 7.6178 | 7.7107 | 7.8036 | 7.8965 | 7.9894 | 8.0823 | 8.1752 | 8.2681 |
| 90 | 8.3610 | 8.4539 | 8.5468 | 8.6397 | 8.7326 | 8.8255 | 8.9184 | 9.0113 | 9.1042 | 9.1971 |

English Square Inches = Square Centimetres.

| Sq. ins | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0 | 0.0000 | 6.4514 | 12.903 | 19.354 | 25.805 | 32.257 | 38.708 | 45.160 | 51.611 | 58.062 |
| 10 | 64.514 | 70.965 | 77.416 | 83.868 | 90.319 | 96.771 | 103.22 | 109.67 | 116.13 | 122.58 |
| 20 | 129.08 | 135.48 | 141.93 | 148.38 | 154.83 | 161.28 | 167.74 | 174.19 | 180.64 | 187.09 |
| 30 | 193.54 | 199.99 | 206.44 | 212.90 | 219.35 | 225.80 | 232.25 | 238.70 | 245.15 | 251.60 |
| 40 | 258.05 | 264.51 | 270.96 | 277.41 | 283.86 | 290.31 | 296.76 | 303.21 | 309.67 | 316.12 |
| 50 | 322.57 | 329.02 | 335.47 | 341.92 | 348.37 | 354.83 | 361.28 | 367.73 | 374.18 | 380.63 |
| 60 | 387.08 | 393.53 | 399.98 | 406.44 | 412.89 | 419.34 | 425.79 | 432.24 | 438.69 | 445.14 |
| 70 | 451.60 | 458.05 | 464.50 | 470.95 | 477.40 | 483.85 | 490.30 | 496.76 | 503.21 | 509.66 |
| 80 | 516.11 | 522.56 | 529.01 | 535.46 | 541.91 | 548.37 | 554.82 | 561.27 | 567.72 | 574.17 |
| 90 | 580.62 | 587.07 | 593.52 | 599.98 | 606.43 | 612.88 | 619.33 | 625.78 | 632.23 | 638.68 |

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English Cubic Feet = Cubic Metres.

| Cub. ft. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0 | 0.0000 | 0.0283 | 0.0566 | 0.0849 | 0.1133 | 0.1416 | 0.1699 | 0.1982 | 0.2265 | 0.2548 |
| 10 | 0.2832 | 0.3115 | 0.3398 | 0.3681 | 0.3964 | 0.4247 | 0.4530 | 0.4814 | 0.5097 | 0.5380 |
| 20 | 0.5663 | 0.5946 | 0.6229 | 0.6513 | 0.6796 | 0.7079 | 0.7362 | 0.7645 | 0.7928 | 0.8211 |
| 30 | 0.8494 | 0.8777 | 0.9061 | 0.9344 | 0.9627 | 0.9910 | 1.0194 | 1.0477 | 1.0760 | 1.1043 |
| 40 | 1.1326 | 1.1609 | 1.1892 | 1.2176 | 1.2459 | 1.2742 | 1.3025 | 1.3308 | 1.3591 | 1.3875 |
| 50 | 1.4158 | 1.4441 | 1.4724 | 1.5007 | 1.5290 | 1.5573 | 1.5857 | 1.6140 | 1.6423 | 1.6706 |
| 60 | 1.6989 | 1.7272 | 1.7555 | 1.7839 | 1.8122 | 1.8405 | 1.8688 | 1.8971 | 1.9254 | 1.9538 |
| 70 | 1.9821 | 2.0104 | 2.0387 | 2.0670 | 2.0953 | 2.1236 | 2.1520 | 2.1803 | 2.2086 | 2.2369 |
| 80 | 2.2652 | 2.2935 | 2.3219 | 2.3502 | 2.3785 | 2.4068 | 2.4351 | 2.4634 | 2.4917 | 2.5201 |
| 90 | 2.5484 | 2.5767 | 2.6050 | 2.6333 | 2.6616 | 2.6900 | 2.7183 | 2.7466 | 2.7749 | 2.8032 |

English Cubic Inches = Cubic Centimetres.

| Cub. in. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0 | 0.0000 | 16.386 | 32.772 | 49.159 | 65.545 | 81.931 | 98.317 | 114.70 | 131.09 | 147.48 |
| 10 | 163.86 | 180.25 | 196.63 | 213.02 | 229.41 | 245.79 | 262.18 | 278.56 | 294.95 | 311.34 |
| 20 | 327.72 | 344.11 | 360.50 | 376.88 | 393.27 | 409.65 | 426.04 | 442.43 | 458.81 | 475.20 |
| 30 | 491.59 | 507.97 | 524.36 | 540.74 | 557.13 | 573.52 | 589.90 | 606.29 | 622.67 | 639.06 |
| 40 | 655.45 | 671.83 | 688.22 | 704.61 | 720.99 | 737.38 | 753.76 | 770.15 | 786.54 | 802.92 |
| 50 | 819.31 | 835.69 | 852.08 | 868.47 | 884.85 | 901.24 | 917.63 | 934.01 | 950.40 | 966.78 |
| 60 | 983.17 | 999.56 | 1015.9 | 1032.3 | 1048.7 | 1065.1 | 1081.5 | 1097.9 | 1114.3 | 1130.6 |
| 70 | 1147.0 | 1163.4 | 1179.8 | 1196.2 | 1212.6 | 1229.0 | 1245.3 | 1261.7 | 1278.1 | 1294.5 |
| 80 | 1310.9 | 1327.3 | 1343.7 | 1360.1 | 1376.4 | 1392.8 | 1409.2 | 1425.6 | 1442.0 | 1458.4 |
| 90 | 1474.8 | 1491.1 | 1507.5 | 1523.9 | 1540.3 | 1556.7 | 1573.1 | 1589.5 | 1605.8 | 1622.2 |

English Pounds = Kilograms.

| Lbs. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|------|--------|--------|--------|---------|---------|---------|---------|---------|---------|---------|
| 0 | 0.0000 | 0.4536 | 0.9072 | 1.3608 | 1.8144 | 2.2680 | 2.7216 | 3.1751 | 3.6287 | 4.0823 |
| 10 | 4.5359 | 4.9895 | 5.4431 | 5.8967 | 6.3503 | 6.8039 | 7.2575 | 7.7111 | 8.1647 | 8.6183 |
| 20 | 9.0719 | 9.5254 | 9.9790 | 10.4326 | 10.8862 | 11.3398 | 11.7934 | 12.2470 | 12.7006 | 13.1542 |
| 30 | 13.608 | 14.061 | 14.515 | 14.969 | 15.422 | 15.876 | 16.329 | 16.783 | 17.237 | 17.690 |
| 40 | 18.144 | 18.597 | 19.051 | 19.504 | 19.958 | 20.412 | 20.865 | 21.319 | 21.772 | 22.226 |
| 50 | 22.680 | 23.133 | 23.587 | 24.040 | 24.494 | 24.948 | 25.401 | 25.855 | 26.308 | 26.762 |
| 60 | 27.216 | 27.669 | 28.123 | 28.576 | 29.030 | 29.484 | 29.937 | 30.391 | 30.844 | 31.298 |
| 70 | 31.751 | 32.205 | 32.659 | 33.112 | 33.566 | 34.019 | 34.473 | 34.927 | 35.380 | 35.834 |
| 80 | 36.287 | 36.741 | 37.195 | 37.648 | 38.102 | 38.555 | 39.009 | 39.463 | 39.916 | 40.370 |
| 90 | 40.823 | 41.277 | 41.731 | 42.184 | 42.638 | 43.091 | 43.545 | 43.998 | 44.452 | 44.906 |

WEIGHTS AND MEASURES

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English Tons = Kilograms.

| Tons. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| 0 | 0.0000 | 1016 | 2032 | 3048 | 4064 | 5080 | 6096 | 7112 | 8129 | 9145 |
| 10 | 10161 | 11177 | 12193 | 13209 | 14225 | 15241 | 16257 | 17273 | 18289 | 19305 |
| 20 | 20321 | 21337 | 22353 | 23369 | 24386 | 25402 | 26418 | 27434 | 28450 | 29466 |
| 30 | 30482 | 31498 | 32514 | 33530 | 34546 | 35562 | 36578 | 37594 | 38610 | 39627 |
| 40 | 40648 | 41665 | 42675 | 43691 | 44707 | 45723 | 46739 | 47755 | 48771 | 49787 |
| 50 | 50808 | 51819 | 52835 | 53851 | 54868 | 55884 | 56900 | 57916 | 58932 | 59948 |
| 60 | 60964 | 61980 | 62996 | 64012 | 65028 | 66044 | 67060 | 68076 | 69092 | 70108 |
| 70 | 71125 | 72141 | 73157 | 74173 | 75189 | 76205 | 77221 | 78237 | 79253 | 80269 |
| 80 | 81285 | 82302 | 83317 | 84333 | 85348 | 86364 | 87382 | 88398 | 89414 | 90430 |
| 90 | 91446 | 92466 | 93478 | 94494 | 95510 | 96526 | 97542 | 98558 | 99574 | 100590 |

English Grains = Grams.

| Grains. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1 | 0 | .065 | .1296 | .194 | .259 | .324 | .389 | .454 | .518 | .583 |
| 10 | .648 | .713 | .778 | .842 | .907 | .972 | 1.037 | 1.102 | 1.166 | 1.231 |
| 20 | 1.296 | 1.361 | 1.426 | 1.490 | 1.555 | 1.620 | 1.685 | 1.749 | 1.814 | 1.879 |
| 30 | 1.944 | 2.009 | 2.074 | 2.138 | 2.203 | 2.268 | 2.333 | 2.397 | 2.462 | 2.527 |
| 40 | 2.592 | 2.657 | 2.721 | 2.786 | 2.851 | 2.916 | 2.981 | 3.045 | 3.110 | 3.175 |
| 50 | 3.240 | 3.305 | 3.369 | 3.434 | 3.499 | 3.564 | 3.629 | 3.693 | 3.758 | 3.823 |
| 60 | 3.888 | 3.953 | 4.018 | 4.082 | 4.147 | 4.212 | 4.277 | 4.341 | 4.406 | 4.471 |
| 70 | 4.536 | 4.601 | 4.666 | 4.730 | 4.795 | 4.860 | 4.925 | 4.989 | 5.054 | 5.119 |
| 80 | 5.184 | 5.249 | 5.314 | 5.378 | 5.443 | 5.508 | 5.573 | 5.637 | 5.702 | 5.767 |
| 90 | 5.832 | 5.897 | 5.962 | 6.026 | 6.091 | 6.156 | 6.221 | 6.286 | 6.350 | 6.415 |

Grams = English Grains.

| Grams. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0 | 0 | 1.543 | 3.086 | 4.629 | 6.172 | 7.716 | 9.259 | 10.802 | 12.345 | 13.888 |
| 1 | 15.432 | 16.975 | 18.518 | 20.061 | 21.604 | 23.148 | 24.691 | 26.234 | 27.777 | 29.320 |
| 2 | 30.864 | 32.407 | 33.950 | 35.493 | 37.036 | 38.580 | 40.123 | 41.666 | 43.209 | 44.752 |
| 3 | 46.296 | 47.839 | 49.382 | 50.925 | 52.468 | 54.012 | 55.555 | 57.098 | 58.641 | 60.184 |
| 4 | 61.728 | 63.271 | 64.814 | 66.357 | 67.900 | 69.444 | 70.987 | 72.530 | 74.073 | 75.616 |
| 5 | 77.160 | 78.703 | 80.246 | 81.789 | 83.332 | 84.875 | 86.419 | 87.962 | 89.505 | 91.048 |

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Conversion of English to Metric Measures.

- 1 English pound (lb.) per sq. foot = 4·883 kg. per sq. metre (sq. m.).
- 1 " " " sq. inch = 0·07031 kg. per sq. m.
- 1 " ton per sq. inch = 158 kg. per sq. cm.
- 1 " pound per cub. foot = 16·02 gm. per litre.
- 1 kilogram per sq. metre = 0·2048 lb. per sq. foot.
- 1 English grain per gallon = 0·014286 gm. per litre.
- 1 " " " English cub. foot = 2·287 gm. per cub. metre.
- 1 grm. per litre = 70 grains per gallon = 0·06243 lb. per cub. foot.
- 1 metre-kilogram (mkg.) = 7·235 foot pounds.
- 1 foot-pound = 0·1382 mkg.
- 1 foot-pound per cub. foot = 4·8807 mkg. per cub. met.

(See also page 109 for other figures used in converting English to metric measures and *vice versa*.)

TABLE 4.—COMPARISON OF THERMOMETRIC SCALES.

$$t^{\circ}\text{C} = \frac{1}{5}t^{\circ}\text{R} = \frac{9}{5}t + 32^{\circ}\text{F}; t^{\circ}\text{R} = \frac{5}{9}t^{\circ}\text{C} = \frac{9}{5}t + 32^{\circ}\text{F}; t^{\circ}\text{F} = \frac{5}{9}(t - 32^{\circ})\text{C} = \frac{4}{5}(t - 32^{\circ})\text{R}.$$

Celsius' (Centigrade) degrees as units.

| Cels. | Réau. | Fahr. | Cels. | Réau. | Fahr. | Cels. | Réau. | Fahr. | Cels. | Réau. | Fahr. | Réau. | Fahr. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| -40 | -32 | -40 | -15 | -12.8 | +3.2 | +8 | +6.4 | +46.4 | +32 | +25.6 | +89.6 | +55 | +44 |
| 39 | 31.2 | 38.2 | 15 | 12 | 5 | 9 | 7.2 | 48.2 | 33 | 26.4 | 91.4 | 56 | 44.8 |
| 38 | 30.4 | 36.4 | 14 | 11.2 | 6.8 | 10 | 8 | 50 | 34 | 27.2 | 93.2 | 57 | 45.6 |
| 37 | 29.6 | 34.6 | 13 | 10.4 | 8.6 | 11 | 8.8 | 51.8 | 35 | 28 | 95 | 58 | 46.4 |
| 36 | 28.8 | 32.8 | 12 | 9.6 | 10.4 | 12 | 9.6 | 53.6 | 36 | 28.8 | 96.8 | 59 | 47.2 |
| 35 | 28 | 31 | 11 | 8.8 | 12.2 | 13 | 10.4 | 55.4 | 37 | 29.6 | 98.6 | 60 | 48 |
| 34 | 27.2 | 29.2 | 10 | 8 | 14 | 14 | 11.2 | 57.2 | 38 | 30.4 | 100.4 | 61 | 48.8 |
| 33 | 26.4 | 27.4 | 9 | 7.2 | 15.8 | 15 | 12 | 59 | 39 | 31.2 | 102.2 | 62 | 49.6 |
| 32 | 25.6 | 25.6 | 8 | 6.4 | 17.6 | 16 | 12.8 | 60.8 | 40 | 32 | 104 | 63 | 50.4 |
| 31 | 24.8 | 23.8 | 7 | 5.6 | 19.4 | 17 | 13.6 | 62.6 | 41 | 32.8 | 105.8 | 64 | 51.2 |
| 30 | 24 | 22 | 6 | 4.8 | 21.2 | 18 | 14.4 | 64.4 | 42 | 33.6 | 107.6 | 65 | 52 |
| 29 | 23.2 | 20.2 | 5 | 4 | 23 | 19 | 15.2 | 66.2 | 43 | 34.4 | 109.4 | 66 | 52.8 |
| 28 | 22.4 | 18.4 | 4 | 3.2 | 24.8 | 20 | 16 | 68 | 44 | 35.2 | 111.2 | 67 | 53.6 |
| 27 | 21.6 | 16.6 | 3 | 2.4 | 26.6 | 21 | 16.8 | 69.8 | 45 | 36 | 113 | 68 | 54.4 |
| 26 | 20.8 | 14.8 | 2 | 1.6 | 28.4 | 22 | 17.6 | 71.6 | 46 | 36.8 | 114.8 | 69 | 55.2 |
| 25 | 20 | 13 | 1 | 0.8 | 30.2 | 23 | 18.4 | 73.4 | 47 | 37.6 | 116.6 | 70 | 56 |
| 24 | 19.2 | 11.2 | 0 | 0 | 32 | 24 | 19.2 | 75.2 | 48 | 38.4 | 118.4 | 71 | 56.8 |
| 23 | 18.4 | 9.4 | +1 | +0.8 | 33.8 | 25 | 20 | 77 | 49 | 39.2 | 120.2 | 72 | 57.6 |
| 22 | 17.6 | 7.6 | 2 | 1.6 | 35.6 | 26 | 20.8 | 78.8 | 50 | 40 | 122 | 73 | 58.4 |
| 21 | 16.8 | 5.8 | 3 | 2.4 | 37.4 | 27 | 21.6 | 80.6 | 51 | 40.8 | 123.8 | 74 | 59.2 |
| 20 | 16 | 4 | 4 | 3.2 | 39.2 | 28 | 22.4 | 82.4 | 52 | 41.6 | 125.6 | 75 | 60 |
| 19 | 15.2 | 2.2 | 5 | 4 | 41 | 29 | 23.2 | 84.2 | 53 | 42.4 | 127.4 | 76 | 60.8 |
| 18 | 14.4 | 0.4 | 6 | 4.8 | 42.8 | 30 | 24 | 86 | 54 | 43.2 | 129.2 | 77 | 61.6 |
| 17 | 13.6 | +1.4 | 7 | 5.6 | 44.6 | 31 | 24.8 | 87.8 | ... | ... | ... | ... | ... |
| | | | | | | | | | + | 62.4 | 131 | 78 | + |
| | | | | | | | | | 63.2 | 132.8 | 79 | 63.2 | 172.4 |
| | | | | | | | | | 64 | 134.6 | 80 | 64 | 174.2 |
| | | | | | | | | | 64.8 | 136.4 | 81 | 64.8 | 176 |
| | | | | | | | | | 65.6 | 138.2 | 82 | 65.6 | 177.8 |
| | | | | | | | | | 66.4 | 140 | 83 | 66.4 | 179.6 |
| | | | | | | | | | 67.2 | 141.8 | 84 | 67.2 | 181.4 |
| | | | | | | | | | 68 | 143.6 | 85 | 68 | 183.2 |
| | | | | | | | | | 68.8 | 145.4 | 86 | 68.8 | 185 |
| | | | | | | | | | 69.6 | 147.2 | 87 | 69.6 | 186.8 |
| | | | | | | | | | 70.4 | 149 | 88 | 70.4 | 188.6 |
| | | | | | | | | | 71.2 | 150.8 | 89 | 71.2 | 190.4 |
| | | | | | | | | | 72 | 152.6 | 90 | 72 | 192.2 |
| | | | | | | | | | 72.8 | 154.4 | 91 | 72.8 | 194 |
| | | | | | | | | | 73.6 | 156.2 | 92 | 73.6 | 195.8 |
| | | | | | | | | | 74.4 | 158 | 93 | 74.4 | 197.6 |
| | | | | | | | | | 75.2 | 159.8 | 94 | 75.2 | 199.4 |
| | | | | | | | | | 76 | 161.6 | 95 | 76 | 201.2 |
| | | | | | | | | | 76.8 | 163.4 | 96 | 76.8 | 203 |
| | | | | | | | | | 77.6 | 165.2 | 97 | 77.6 | 204.8 |
| | | | | | | | | | 78.4 | 167 | 98 | 78.4 | 206.6 |
| | | | | | | | | | 79.2 | 168.8 | 99 | 79.2 | 208.4 |
| | | | | | | | | | 80 | 170.6 | 100 | 80 | 210.2 |
| | | | | | | | | | ... | ... | ... | ... | 212 |
| | | | | | | | | | ... | ... | ... | ... | ... |

CONVERSION OF CENTIGRADE INTO FAHR. 15

TABLE 6.—CONVERSION OF CENTIGRADE INTO FAHRENHEIT DEGREES ABOVE 100, AND VICE VERSA.

Divide the degrees above 100 into hundreds and a remainder. The figure corresponding to the hundreds is taken from the following tables and added to that corresponding to the remainder as taken from Table 4. If, on converting Fahrenheit into Centigrade, the "remainder" amounts to 32°, or less, the degrees Centigrade corresponding to it are negative (below freezing point), and hence must be *deducted* from the figures of the following table. Also note, for example, that 300° F. is not = 166·7° C., but = 166·7 - 17·8, = 148·9° C.

A.

| C. | Fahr. | C. | Fahr. | C. | Fahr. | C. | Fahr. |
|-----|-------|------|-------|------|-------|------|-------|
| 100 | 180 | 600 | 1080 | 1100 | 1980 | 1600 | 2880 |
| 200 | 360 | 700 | 1260 | 1200 | 2160 | 1700 | 3060 |
| 300 | 540 | 800 | 1440 | 1300 | 2340 | 1800 | 3240 |
| 400 | 720 | 900 | 1620 | 1400 | 2520 | 1900 | 3420 |
| 500 | 900 | 1000 | 1800 | 1500 | 2700 | 2000 | 3600 |

B.

| Fahr. | C. | Fahr. | C. | Fahr. | C. | Fahr. | C. |
|-------|-------|-------|-------|-------|--------|-------|--------|
| 100 | 55·6 | 1000 | 556·6 | 1900 | 1055·6 | 2800 | 1555·6 |
| 200 | 111·1 | 1100 | 611·1 | 2000 | 1111·1 | 2900 | 1611·1 |
| 300 | 166·7 | 1200 | 666·7 | 2100 | 1166·7 | 3000 | 1666·7 |
| 400 | 222·2 | 1300 | 722·2 | 2200 | 1222·2 | 3100 | 1722·2 |
| 500 | 277·8 | 1400 | 777·8 | 2300 | 1277·8 | 3200 | 1777·8 |
| 600 | 333·3 | 1500 | 833·3 | 2400 | 1333·3 | 3300 | 1833·3 |
| 700 | 388·9 | 1600 | 888·9 | 2500 | 1388·9 | 3400 | 1888·9 |
| 800 | 444·4 | 1700 | 944·4 | 2600 | 1444·4 | 3500 | 1944·4 |
| 900 | 500 | 1800 | 1000 | 2700 | 1500 | ... | ... |

TABLE 7.—THE UNITS OF ENERGY AND WORK.

The "absolute" unit of mechanical energy, the **erg**, is the product of the unit of length into the "absolute" unit of force, or **dynes**, i.e., the force necessary to impart to a mass of 1 gram in a second a velocity of 1 cm. per second.

For most purposes, it is more convenient to use a gravitation unit, in the definition of which the value of the earth's gravitation attraction for bodies on its surface is involved. The unit of force, thus defined, is the weight of 1 gram and is equal to 981 dynes. The corresponding unit of mechanical energy is the product of this unit into the unit of length, i.e., the **gram-centimetre**.

The relations between the mechanical unit of energy and the units of heat and electricity are given in Tables 8 and 10.

TABLE 8.—THE UNIT OF HEAT.

The usual unit of heat for chemical purposes is the "small calorie" or **gram-calorie** (cal.). It is roughly defined as the quantity of heat required to raise 1 gram of water 1° C., but as this quantity is not exactly the same for all temperatures, it is necessary to specify the temperature. The normal calorie is that which raises 1 gram of water from 14.5° to 15.5°.

The great or **kilogram-calorie** (Cal.) is 1000 times the small calorie. The **centuple-calorie** (K) is the quantity of heat required to raise 1 gram of water from 0° to 100°, and is very nearly equal to 100 small calories. We have then

$$1 \text{ Cal.} = 10 \text{ K} = 1000 \text{ cal.}$$

Another unit of heat used for thermochemical work is the **joule**, which is equivalent to 10,000,000 ergs. It is denoted by the letter **j**, while a larger unit, the **kilojoule**, equal to 1000 **j** is denoted by the symbol **Kj**. The relations between these and the calorie are as follows:—

$$\begin{array}{ll} 1 \text{ cal} = 4.189 \text{ j.} & 1 \text{ j} = 0.2387 \text{ cal.} \\ 1 \text{ Cal} = 4.189 \text{ Kj.} & 1 \text{ Kj} = 0.2387 \text{ Cal.} \end{array}$$

The **British heat-unit**, is the quantity of heat required to raise 1 pound of water from 32° to 33° Fahr. and is = 252 gram-calories. The British thermal unit is denoted by the symbol **B.Th.U.**

TABLE 8—*Continued.*(a) **Calorific Value of Fuels.**

(The data given are the *upper* heating values, i.e., they are referred to the combustion of hydrogen to liquid water as found in the calorimeter.)

| | gram-cal. | | gram-cal. |
|--------------------------------------|-----------|-------------------------|-----------|
| Ether | 9,000 | Petroleum residue . . . | 10,500 |
| Alcohol | 7,100 | Petroleum | 11,000 |
| Lignite-tar oil | 9,950 | Fatty oils | 9,300 |
| Wood | 4,100 | Tallow | 8,370 |
| Methyl alcohol | 5,300 | Beeswax | 9,000 |
| Charcoal (C to CO ₂) . . | 8,000 | Cellulose | 4,200 |
| „ (C to CO) | 2,300 | | |

(b) **Calorific Value of Gases.**

| | Molec. Weight. | Calories when one gram-mol. is burnt to | | Calories per cub. met. when burnt to | |
|--|----------------|---|--------|--------------------------------------|--------|
| | | Liquid Water. | Steam. | Liquid Water. | Steam. |
| Hydrogen, H ₂ | 2 | 69·0 | 58·1 | 3064 | 2585 |
| Methane, CH ₄ | 16 | 213·5 | 192·1 | 9565 | 8606 |
| Ethylene, C ₂ H ₄ | 28 | 334·8 | 313·4 | 14,999 | 14,060 |
| Benzene vapour, C ₆ H ₆ . . | 78 | 788·0 | 755·9 | 35,302 | 33,864 |
| Naphthalene vapour, C ₁₀ H ₈ | 128 | 1258·4 | 1230·6 | 50,376 | 55,131 |
| Carbon monoxide, CO . . | 28 | 68·4 | 68·4 | 3064 | 3064 |

TABLE 9.—THE EVAPORATION UNIT.

(G. A. Rossetti.)

After the fundamental unit, the British thermal unit (B.Th.U.), the most important unit of heat measurement in use among engineers is the evaporation unit (ev.u.). The B.Th.U. means the amount of heat needed to raise 1 lb. of water 1° F. at the mean specific heat of water between 32° F. and 212° F.; the ev.u. means the amount of heat needed to convert 1 lb. of water at 212° F. into saturated steam at the same temperature and consequently at the atmospheric pressure of 14·7 lb. per sq. in.

TABLE 9—Continued.

In the case of boilers generating steam for power production and for various industrial uses, the conditions of this steam generation vary widely, and, in order readily to compare results from different sources, it is customary to reduce the boiler output to evaporation units (sometimes termed "lb. evaporated as from and at 212° F."). For this reduction it is necessary to know the equivalent of the evaporation unit in British thermal units. This equivalent is given in the steam tables, the best known of which are those of Professors Callendar, Marks and Davis, and Peabody. Of these, Professor Callendar's table is probably the most reliable, being founded on the soundest basis yet possible, both theoretical and experimental. The table of Professors Marks and Davis is recognised as standard in the United States, and is frequently specified as the basis for test calculations by British engineers. Professor Peabody's table, though perhaps somewhat superseded by the two later tables, was undoubtedly the best authority on the subject twelve years ago, when its eighth edition was published. Naturally, the principal differences between these tables occur in regard to the properties of steam at the higher temperatures and pressures, where experimental difficulties are most serious. But there is not absolute agreement as to the fundamental constant, the number of British thermal units equivalent to one evaporation unit. The following table gives the equivalent of the ev.u. in B.Th.U. according to each of the three authorities above mentioned, and also gives the conversion factor for each of the values of the ev.u. in terms of each of the others, and for the number of ev.u. equivalent to 1000 B.Th.U. The logarithm of each of the

CONVERSION FACTORS AND LOGARITHMS.

| | Factor. | Logarithm. |
|-------------------|------------------------------|--------------|
| 1 Ev.u. (C.) | = 970·74 B.Th.U. | 2·98710298 |
| | = 1·00035037 Ev.u. (M. & D.) | 0·00015214 |
| | = 1·00107250 Ev.u. (P.) | 0·00046553 |
| 1 Ev.u. (M. & D.) | = 970·4 B.Th.U. | 2·98695079 |
| | = 0·99964976 Ev.u. (C.) | 0·99984786-1 |
| | = 1·00072187 Ev.u. (P.) | 0 00031839 |
| 1 Ev.u. (P) | = 969·7 B.Th.U. | 2·98663740 |
| | = 0·99892865 Ev.u. (C.) | 0·99953447-1 |
| | = 0·99927865 Ev.u. (M. & D.) | 0·99968661-1 |
| 1,000 B.Th.U. | = 1·03014195 Ev.u. (C.) | 0·01289707 |
| | = 1·03050288 Ev.u. (M. & D.) | 0·01304921 |
| | = 1·03124679 Ev.u. (P.) | 0·01336260 |

conversion factors is also given, thus providing assistance for calculations. The several values of the evaporation unit are referred to by the initials (C.), (M. and D.), (P.).

TABLE 10.—ELECTRICAL UNITS.

A joule or watt-second is the unit of electrical energy and is defined as the energy expended in one second by an unvarying electric current of one ampere flowing under an electrical pressure of one volt.

For technical use, the above units are inconveniently small and the following are the units commonly used in practice.

A kilowatt (K.W.) is 1000 watts. The kilowatt-hour, 1000 watt-hours, is commonly known in this country as the Board of Trade Unit (B.T.U.).

One horse-power (H.P.) is 746 watts. (The value taken for one H.P. in Germany is 736 watts.)

The kilowatt-hour (K.W.H.) and horse-power hour (H.P.H.) are the energy units which represent the energy consumption per hour of systems absorbing energy at the respective rates of one kilowatt and one horse-power. A horse-power year is not a recognised unit, but an H.P. year is generally taken as 8760 H.P.H. The quantitative relations between electrical energy and heat energy are as follows :—

1 joule = 0·23835 *cal.* (gram-calories).

1 kilo-joule (kilowatt-second) = 0·23865 *Cal.* (kilogram-calories).

1 *cal.* = 4·189 joules.

1 *Cal.* = 4·189 kilowatt-seconds.

TABLE 11.—ELECTRO-CHEMICAL EQUIVALENTS.

The separation of a gram equivalent requires 96,540 coulombs = 26·86 ampere hours. 1 ampere hour is capable of yielding :—

| | Grams. | | Grams. |
|---|--------|-------------------------------|--------|
| Silver | 4·0228 | Platinum | 3·6895 |
| Copper (from solutions of cupric salts) | 1·1852 | Mercury | 3·7290 |
| Zinc | 1·219 | Tin | 2·2188 |
| Nickel | 1·0941 | Chlorine | 1·8223 |
| Hydrogen | 0·0876 | Bromine | 2·982 |
| Aluminium | 0·3369 | Iodine | 4·7828 |
| Lead | 8·862 | Oxygen | 0·2983 |
| Gold | 2·4512 | Potassium chlorate | 0·7618 |
| Potassium | 1·4580 | Potassium hydroxide | 2·094 |
| Magnesium | 0·4584 | Sodium hydroxide | 1·494 |

TABLE 12.—REDUCTION OF THE VOLUME OF

$$\text{General formula for Dry Gases, } V_0 = \frac{V \times 273b}{(273 + t)760}$$

b = Barometric pressure, reduced to 0°; t = temperature; f = tension

I. Table for reducing the volumes of

| 0°. | 1°. | 2°. | 3°. | 4°. | 5°. | 6°. | 7°. | 8°. | 9°. | 10°. | 0°. |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1 | 0.996 | 0.993 | 0.989 | 0.986 | 0.982 | 0.978 | 0.975 | 0.972 | 0.968 | 0.965 | 1 |
| 2 | 1.998 | 1.985 | 1.978 | 1.971 | 1.964 | 1.957 | 1.950 | 1.943 | 1.936 | 1.929 | 2 |
| 3 | 2.989 | 2.978 | 2.967 | 2.957 | 2.946 | 2.936 | 2.925 | 2.915 | 2.904 | 2.894 | 3 |
| 4 | 3.985 | 3.971 | 3.956 | 3.942 | 3.928 | 3.914 | 3.900 | 3.886 | 3.872 | 3.859 | 4 |
| 5 | 4.982 | 4.964 | 4.946 | 4.928 | 4.910 | 4.893 | 4.876 | 4.858 | 4.841 | 4.824 | 5 |
| 6 | 5.978 | 5.956 | 5.935 | 5.913 | 5.892 | 5.871 | 5.850 | 5.830 | 5.809 | 5.788 | 6 |
| 7 | 6.974 | 6.949 | 6.924 | 6.899 | 6.874 | 6.850 | 6.825 | 6.801 | 6.777 | 6.753 | 7 |
| 8 | 7.970 | 7.942 | 7.913 | 7.885 | 7.856 | 7.828 | 7.800 | 7.773 | 7.745 | 7.718 | 8 |
| 9 | 8.967 | 8.934 | 8.902 | 8.870 | 8.838 | 8.807 | 8.775 | 8.744 | 8.713 | 8.682 | 9 |
| 10 | 9.963 | 9.927 | 9.891 | 9.856 | 9.820 | 9.785 | 9.750 | 9.716 | 9.681 | 9.647 | 10 |
| 11 | 10.96 | 10.92 | 10.88 | 10.84 | 10.80 | 10.76 | 10.78 | 10.69 | 10.65 | 10.61 | 11 |
| 12 | 11.96 | 11.91 | 11.87 | 11.83 | 11.78 | 11.74 | 11.70 | 11.66 | 11.62 | 11.57 | 12 |
| 13 | 12.95 | 12.91 | 12.86 | 12.81 | 12.76 | 12.72 | 12.68 | 12.63 | 12.59 | 12.54 | 13 |
| 14 | 13.95 | 13.90 | 13.85 | 13.80 | 13.75 | 13.70 | 13.65 | 13.60 | 13.55 | 13.50 | 14 |
| 15 | 14.95 | 14.89 | 14.84 | 14.78 | 14.73 | 14.68 | 14.63 | 14.57 | 14.52 | 14.47 | 15 |
| 16 | 15.94 | 15.88 | 15.83 | 15.77 | 15.71 | 15.66 | 15.60 | 15.55 | 15.49 | 15.43 | 16 |
| 17 | 16.94 | 16.87 | 16.82 | 16.75 | 16.69 | 16.64 | 16.58 | 16.52 | 16.46 | 16.40 | 17 |
| 18 | 17.93 | 17.87 | 17.81 | 17.74 | 17.67 | 17.61 | 17.55 | 17.49 | 17.43 | 17.36 | 18 |
| 19 | 18.93 | 18.86 | 18.79 | 18.72 | 18.65 | 18.59 | 18.53 | 18.46 | 18.39 | 18.33 | 19 |
| 20 | 19.93 | 19.85 | 19.78 | 19.71 | 19.64 | 19.57 | 19.50 | 19.43 | 19.36 | 19.29 | 20 |
| 21 | 20.93 | 20.84 | 20.77 | 20.69 | 20.62 | 20.55 | 20.48 | 20.40 | 20.33 | 20.26 | 21 |
| 22 | 21.92 | 21.84 | 21.76 | 21.68 | 21.60 | 21.53 | 21.45 | 21.37 | 21.30 | 21.22 | 22 |
| 23 | 22.92 | 22.83 | 22.75 | 22.66 | 22.58 | 22.51 | 22.43 | 22.35 | 22.26 | 22.18 | 23 |
| 24 | 23.92 | 23.82 | 23.74 | 23.65 | 23.56 | 23.48 | 23.40 | 23.32 | 23.23 | 23.15 | 24 |
| 25 | 24.91 | 24.81 | 24.73 | 24.64 | 24.55 | 24.46 | 24.38 | 24.29 | 24.20 | 24.11 | 25 |
| 26 | 25.91 | 25.81 | 25.72 | 25.62 | 25.53 | 25.44 | 25.35 | 25.26 | 25.17 | 25.08 | 26 |
| 27 | 26.90 | 26.80 | 26.71 | 26.61 | 26.52 | 26.42 | 26.33 | 26.23 | 26.13 | 26.04 | 27 |
| 28 | 27.90 | 27.79 | 27.69 | 27.59 | 27.50 | 27.40 | 27.30 | 27.20 | 27.10 | 27.01 | 28 |
| 29 | 28.90 | 28.78 | 28.68 | 28.58 | 28.48 | 28.38 | 28.28 | 28.17 | 28.07 | 27.97 | 29 |
| 30 | 29.89 | 29.78 | 29.67 | 29.57 | 29.46 | 29.36 | 29.25 | 29.15 | 29.04 | 28.94 | 30 |
| 31 | 30.89 | 30.77 | 30.66 | 30.55 | 30.44 | 30.34 | 30.23 | 30.12 | 30.01 | 29.91 | 31 |
| 32 | 31.88 | 31.76 | 31.65 | 31.54 | 31.42 | 31.32 | 31.20 | 31.09 | 30.98 | 30.87 | 32 |
| 33 | 32.88 | 32.76 | 32.64 | 32.52 | 32.40 | 32.30 | 32.18 | 32.06 | 31.94 | 31.84 | 33 |
| 34 | 33.88 | 33.75 | 33.63 | 33.51 | 33.39 | 33.27 | 33.15 | 33.03 | 32.91 | 32.80 | 34 |
| 35 | 34.87 | 34.74 | 34.62 | 34.50 | 34.37 | 34.25 | 34.13 | 34.01 | 33.88 | 33.77 | 35 |
| 36 | 35.87 | 35.74 | 35.61 | 35.48 | 35.35 | 35.23 | 35.10 | 34.98 | 34.85 | 34.73 | 36 |
| 37 | 36.87 | 36.73 | 36.60 | 36.47 | 36.33 | 36.21 | 36.08 | 35.95 | 35.82 | 35.70 | 37 |
| 38 | 37.86 | 37.72 | 37.59 | 37.45 | 37.32 | 37.19 | 37.05 | 36.92 | 36.79 | 36.66 | 38 |
| 39 | 38.86 | 38.71 | 38.58 | 38.44 | 38.30 | 38.16 | 38.03 | 37.89 | 37.75 | 37.62 | 39 |
| 40 | 39.85 | 39.71 | 39.56 | 39.42 | 39.28 | 39.14 | 39.00 | 38.86 | 38.72 | 38.59 | 40 |
| 41 | 40.85 | 40.70 | 40.55 | 40.41 | 40.26 | 40.12 | 39.98 | 39.83 | 39.69 | 39.55 | 41 |
| 42 | 41.85 | 41.69 | 41.54 | 41.39 | 41.24 | 41.10 | 40.95 | 40.80 | 40.66 | 40.52 | 42 |
| 43 | 42.84 | 42.68 | 42.53 | 42.38 | 42.22 | 42.08 | 41.93 | 41.78 | 41.62 | 41.48 | 43 |
| 44 | 43.84 | 43.68 | 43.52 | 43.37 | 43.20 | 43.05 | 42.90 | 42.75 | 42.59 | 42.45 | 44 |
| 45 | 44.84 | 44.67 | 44.51 | 44.35 | 44.19 | 44.03 | 43.88 | 43.72 | 43.56 | 43.41 | 45 |
| 46 | 45.83 | 45.66 | 45.50 | 45.34 | 45.17 | 45.01 | 44.85 | 44.69 | 44.53 | 44.38 | 46 |
| 47 | 46.83 | 46.65 | 46.48 | 46.32 | 46.15 | 45.99 | 45.83 | 45.66 | 45.50 | 45.34 | 47 |
| 48 | 47.83 | 47.65 | 47.48 | 47.31 | 47.13 | 46.97 | 46.80 | 46.63 | 46.47 | 46.31 | 48 |
| 49 | 48.82 | 48.64 | 48.47 | 48.29 | 48.12 | 47.95 | 47.78 | 47.60 | 47.44 | 47.27 | 49 |
| 50 | 49.82 | 49.64 | 49.46 | 49.28 | 49.10 | 48.93 | 48.75 | 48.58 | 48.41 | 48.24 | 50 |

GASES TO NORMAL TEMPERATURE & PRESSURE.

General formula for Moist Gases, $V_0 = \frac{V \times 273(b-f)}{(273+t)760}$

of aqueous vapour at t° . Compare Table 18.
gases to a temperature of 0°C .

| 0°. | 1°. | 2°. | 3°. | 4°. | 5°. | 6°. | 7°. | 8°. | 9°. | 10°. | 0°. |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 51 | 50.82 | 50.68 | 50.45 | 50.26 | 50.08 | 49.91 | 49.78 | 49.55 | 49.88 | 49.21 | 51 |
| 52 | 51.81 | 51.62 | 51.44 | 51.25 | 51.06 | 50.89 | 50.70 | 50.52 | 50.85 | 50.17 | 52 |
| 53 | 52.81 | 52.62 | 52.43 | 52.24 | 52.05 | 51.87 | 51.68 | 51.49 | 51.81 | 51.13 | 53 |
| 54 | 53.81 | 53.61 | 53.42 | 53.22 | 53.03 | 52.84 | 52.65 | 52.46 | 52.28 | 52.10 | 54 |
| 55 | 54.80 | 54.60 | 54.41 | 54.21 | 54.01 | 53.82 | 53.63 | 53.44 | 53.25 | 53.06 | 55 |
| 56 | 55.80 | 55.60 | 55.40 | 55.19 | 54.99 | 54.80 | 54.60 | 54.41 | 54.22 | 54.03 | 56 |
| 57 | 56.80 | 56.59 | 56.80 | 56.18 | 55.97 | 55.78 | 55.58 | 55.38 | 55.19 | 54.99 | 57 |
| 58 | 57.79 | 57.58 | 57.87 | 57.66 | 57.45 | 57.24 | 57.04 | 56.85 | 56.65 | 56.46 | 58 |
| 59 | 58.79 | 58.57 | 58.87 | 58.65 | 58.43 | 58.22 | 58.01 | 57.81 | 57.61 | 57.41 | 59 |
| 60 | 59.78 | 59.56 | 59.86 | 59.63 | 59.41 | 59.20 | 58.99 | 58.79 | 58.59 | 58.39 | 60 |
| 61 | 60.78 | 60.56 | 60.84 | 60.62 | 60.40 | 60.19 | 59.98 | 59.78 | 59.58 | 59.38 | 61 |
| 62 | 61.78 | 61.56 | 61.88 | 61.66 | 61.44 | 61.23 | 61.02 | 60.82 | 60.62 | 60.42 | 62 |
| 63 | 62.77 | 62.54 | 62.82 | 62.60 | 62.38 | 62.17 | 61.96 | 61.75 | 61.55 | 61.35 | 63 |
| 64 | 63.77 | 63.54 | 63.81 | 63.59 | 63.37 | 63.16 | 62.95 | 62.74 | 62.54 | 62.34 | 64 |
| 65 | 64.76 | 64.53 | 64.80 | 64.58 | 64.36 | 64.15 | 63.94 | 63.74 | 63.54 | 63.34 | 65 |
| 66 | 65.76 | 65.52 | 65.79 | 65.57 | 65.35 | 65.14 | 64.93 | 64.73 | 64.53 | 64.33 | 66 |
| 67 | 66.75 | 66.51 | 66.78 | 66.56 | 66.34 | 66.13 | 65.92 | 65.72 | 65.52 | 65.32 | 67 |
| 68 | 67.75 | 67.50 | 67.76 | 67.54 | 67.32 | 67.11 | 66.90 | 66.70 | 66.50 | 66.30 | 68 |
| 69 | 68.75 | 68.50 | 68.75 | 68.53 | 68.31 | 68.10 | 67.89 | 67.69 | 67.49 | 67.29 | 69 |
| 70 | 69.74 | 69.49 | 69.74 | 69.51 | 69.29 | 69.08 | 68.87 | 68.67 | 68.47 | 68.27 | 70 |
| 71 | 70.74 | 70.48 | 70.73 | 70.50 | 70.28 | 70.07 | 69.86 | 69.66 | 69.46 | 69.26 | 71 |
| 72 | 71.74 | 71.48 | 71.72 | 71.49 | 71.27 | 71.05 | 70.84 | 70.64 | 70.44 | 70.24 | 72 |
| 73 | 72.73 | 72.47 | 72.71 | 72.48 | 72.25 | 72.03 | 71.82 | 71.62 | 71.42 | 71.22 | 73 |
| 74 | 73.73 | 73.46 | 73.70 | 73.47 | 73.24 | 73.02 | 72.81 | 72.61 | 72.41 | 72.21 | 74 |
| 75 | 74.72 | 74.45 | 74.69 | 74.46 | 74.23 | 74.01 | 73.80 | 73.60 | 73.40 | 73.20 | 75 |
| 76 | 75.72 | 75.45 | 75.68 | 75.45 | 75.22 | 75.00 | 74.79 | 74.59 | 74.39 | 74.19 | 76 |
| 77 | 76.72 | 76.44 | 76.67 | 76.44 | 76.21 | 75.99 | 75.78 | 75.58 | 75.38 | 75.18 | 77 |
| 78 | 77.71 | 77.43 | 77.66 | 77.43 | 77.20 | 76.98 | 76.77 | 76.57 | 76.37 | 76.17 | 78 |
| 79 | 78.71 | 78.42 | 78.65 | 78.42 | 78.19 | 77.97 | 77.76 | 77.56 | 77.36 | 77.16 | 79 |
| 80 | 79.70 | 79.42 | 79.64 | 79.41 | 79.18 | 78.96 | 78.75 | 78.55 | 78.35 | 78.15 | 80 |
| 81 | 80.70 | 80.41 | 80.63 | 80.40 | 80.17 | 79.95 | 79.74 | 79.54 | 79.34 | 79.14 | 81 |
| 82 | 81.69 | 81.40 | 81.62 | 81.39 | 81.16 | 80.94 | 80.73 | 80.53 | 80.33 | 80.13 | 82 |
| 83 | 82.69 | 82.39 | 82.61 | 82.38 | 82.15 | 81.93 | 81.72 | 81.52 | 81.32 | 81.12 | 83 |
| 84 | 83.68 | 83.38 | 83.60 | 83.37 | 83.14 | 82.92 | 82.71 | 82.51 | 82.31 | 82.11 | 84 |
| 85 | 84.68 | 84.38 | 84.60 | 84.37 | 84.14 | 83.92 | 83.71 | 83.51 | 83.31 | 83.11 | 85 |
| 86 | 85.68 | 85.38 | 85.60 | 85.37 | 85.14 | 84.92 | 84.71 | 84.51 | 84.31 | 84.11 | 86 |
| 87 | 86.68 | 86.38 | 86.60 | 86.37 | 86.14 | 85.92 | 85.71 | 85.51 | 85.31 | 85.11 | 87 |
| 88 | 87.67 | 87.37 | 87.59 | 87.36 | 87.13 | 86.91 | 86.70 | 86.50 | 86.30 | 86.10 | 88 |
| 89 | 88.67 | 88.37 | 88.59 | 88.36 | 88.13 | 87.91 | 87.70 | 87.50 | 87.30 | 87.10 | 89 |
| 90 | 89.67 | 89.37 | 89.59 | 89.36 | 89.13 | 88.91 | 88.70 | 88.50 | 88.30 | 88.10 | 90 |
| 91 | 90.66 | 90.36 | 90.58 | 90.35 | 90.12 | 89.90 | 89.69 | 89.49 | 89.29 | 89.09 | 91 |
| 92 | 91.66 | 91.36 | 91.58 | 91.35 | 91.12 | 90.90 | 90.69 | 90.49 | 90.29 | 90.09 | 92 |
| 93 | 92.66 | 92.36 | 92.58 | 92.35 | 92.12 | 91.90 | 91.69 | 91.49 | 91.29 | 91.09 | 93 |
| 94 | 93.66 | 93.36 | 93.58 | 93.35 | 93.12 | 92.90 | 92.69 | 92.49 | 92.29 | 92.09 | 94 |
| 95 | 94.65 | 94.35 | 94.57 | 94.34 | 94.11 | 93.89 | 93.68 | 93.48 | 93.28 | 93.08 | 95 |
| 96 | 95.65 | 95.35 | 95.57 | 95.34 | 95.11 | 94.89 | 94.68 | 94.48 | 94.28 | 94.08 | 96 |
| 97 | 96.64 | 96.34 | 96.56 | 96.33 | 96.10 | 95.88 | 95.67 | 95.47 | 95.27 | 95.07 | 97 |
| 98 | 97.64 | 97.34 | 97.56 | 97.33 | 97.10 | 96.88 | 96.67 | 96.47 | 96.27 | 96.07 | 98 |
| 99 | 98.64 | 98.34 | 98.56 | 98.33 | 98.10 | 97.88 | 97.67 | 97.47 | 97.27 | 97.07 | 99 |
| 100 | 99.63 | 99.33 | 99.55 | 99.32 | 99.09 | 98.87 | 98.66 | 98.46 | 98.26 | 98.06 | 100 |

TABLE 12—

I. Table for reducing the volumes of

| 0°. | 11°. | 12°. | 13°. | 14°. | 15°. | 16°. | 17°. | 18°. | 19°. | 20°. | 0°. |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1 | 0.961 | 0.958 | 0.955 | 0.951 | 0.948 | 0.945 | 0.941 | 0.938 | 0.935 | 0.932 | 1 |
| 2 | 1.923 | 1.916 | 1.909 | 1.903 | 1.896 | 1.889 | 1.885 | 1.876 | 1.869 | 1.864 | 2 |
| 3 | 2.884 | 2.874 | 2.864 | 2.854 | 2.844 | 2.834 | 2.824 | 2.815 | 2.805 | 2.795 | 3 |
| 4 | 3.845 | 3.832 | 3.818 | 3.805 | 3.792 | 3.779 | 3.766 | 3.753 | 3.740 | 3.727 | 4 |
| 5 | 4.807 | 4.790 | 4.773 | 4.757 | 4.740 | 4.724 | 4.707 | 4.691 | 4.675 | 4.659 | 5 |
| 6 | 5.768 | 5.747 | 5.728 | 5.708 | 5.688 | 5.668 | 5.648 | 5.629 | 5.600 | 5.591 | 6 |
| 7 | 6.729 | 6.705 | 6.682 | 6.659 | 6.636 | 6.613 | 6.590 | 6.567 | 6.544 | 6.523 | 7 |
| 8 | 7.690 | 7.663 | 7.637 | 7.610 | 7.584 | 7.558 | 7.531 | 7.506 | 7.479 | 7.454 | 8 |
| 9 | 8.652 | 8.621 | 8.591 | 8.562 | 8.532 | 8.502 | 8.472 | 8.444 | 8.414 | 8.386 | 9 |
| 10 | 9.618 | 9.579 | 9.546 | 9.513 | 9.480 | 9.447 | 9.414 | 9.382 | 9.349 | 9.318 | 10 |
| 11 | 10.57 | 10.53 | 10.50 | 10.46 | 10.43 | 10.39 | 10.35 | 10.32 | 10.28 | 10.25 | 11 |
| 12 | 11.53 | 11.49 | 11.45 | 11.42 | 11.38 | 11.35 | 11.30 | 11.26 | 11.21 | 11.18 | 12 |
| 13 | 12.49 | 12.45 | 12.41 | 12.36 | 12.33 | 12.28 | 12.24 | 12.20 | 12.15 | 12.11 | 13 |
| 14 | 13.45 | 13.41 | 13.36 | 13.31 | 13.27 | 13.22 | 13.17 | 13.13 | 13.08 | 13.04 | 14 |
| 15 | 14.42 | 14.37 | 14.32 | 14.27 | 14.22 | 14.17 | 14.12 | 14.07 | 14.02 | 13.97 | 15 |
| 16 | 15.38 | 15.32 | 15.27 | 15.22 | 15.17 | 15.11 | 15.06 | 15.01 | 14.96 | 14.91 | 16 |
| 17 | 16.34 | 16.28 | 16.23 | 16.17 | 16.12 | 16.06 | 16.00 | 15.95 | 15.89 | 15.84 | 17 |
| 18 | 17.30 | 17.24 | 17.18 | 17.12 | 17.06 | 17.00 | 16.94 | 16.89 | 16.82 | 16.76 | 18 |
| 19 | 18.26 | 18.20 | 18.14 | 18.07 | 18.01 | 17.95 | 17.89 | 17.83 | 17.76 | 17.70 | 19 |
| 20 | 19.23 | 19.16 | 19.09 | 19.03 | 18.96 | 18.89 | 18.83 | 18.76 | 18.69 | 18.64 | 20 |
| 21 | 20.19 | 20.12 | 20.04 | 19.98 | 19.91 | 19.84 | 19.77 | 19.70 | 19.62 | 19.57 | 21 |
| 22 | 21.15 | 21.08 | 21.00 | 20.93 | 20.86 | 20.78 | 20.71 | 20.64 | 20.56 | 20.50 | 22 |
| 23 | 22.11 | 22.03 | 21.95 | 21.88 | 21.80 | 21.73 | 21.65 | 21.58 | 21.50 | 21.48 | 23 |
| 24 | 23.07 | 22.99 | 22.91 | 22.83 | 22.75 | 22.67 | 22.59 | 22.51 | 22.48 | 22.37 | 24 |
| 25 | 24.03 | 23.95 | 23.86 | 23.78 | 23.70 | 23.61 | 23.54 | 23.45 | 23.37 | 23.30 | 25 |
| 26 | 25.00 | 24.91 | 24.81 | 24.73 | 24.65 | 24.56 | 24.48 | 24.39 | 24.30 | 24.23 | 26 |
| 27 | 25.96 | 25.87 | 25.77 | 25.69 | 25.60 | 25.50 | 25.42 | 25.33 | 25.25 | 25.16 | 27 |
| 28 | 26.92 | 26.82 | 26.72 | 26.64 | 26.54 | 26.45 | 26.36 | 26.27 | 26.17 | 26.09 | 28 |
| 29 | 27.88 | 27.78 | 27.68 | 27.59 | 27.49 | 27.39 | 27.30 | 27.20 | 27.10 | 27.02 | 29 |
| 30 | 28.84 | 28.74 | 28.64 | 28.54 | 28.44 | 28.34 | 28.24 | 28.15 | 28.05 | 27.95 | 30 |
| 31 | 29.80 | 29.70 | 29.59 | 29.49 | 29.39 | 29.28 | 29.18 | 29.09 | 28.99 | 28.87 | 31 |
| 32 | 30.76 | 30.66 | 30.55 | 30.44 | 30.34 | 30.23 | 30.12 | 30.03 | 29.92 | 29.81 | 32 |
| 33 | 31.72 | 31.61 | 31.50 | 31.39 | 31.28 | 31.17 | 31.06 | 30.97 | 30.86 | 30.74 | 33 |
| 34 | 32.68 | 32.57 | 32.46 | 32.34 | 32.23 | 32.12 | 32.01 | 31.90 | 31.79 | 31.68 | 34 |
| 35 | 33.65 | 33.53 | 33.41 | 33.30 | 33.18 | 33.06 | 32.95 | 32.84 | 32.73 | 32.61 | 35 |
| 36 | 34.61 | 34.49 | 34.37 | 34.25 | 34.13 | 34.01 | 33.89 | 33.78 | 33.66 | 33.54 | 36 |
| 37 | 35.57 | 35.45 | 35.32 | 35.20 | 35.08 | 34.95 | 34.83 | 34.72 | 34.59 | 34.47 | 37 |
| 38 | 36.53 | 36.40 | 36.28 | 36.15 | 36.02 | 35.90 | 35.77 | 35.66 | 35.53 | 35.40 | 38 |
| 39 | 37.49 | 37.36 | 37.23 | 37.10 | 36.97 | 36.84 | 36.71 | 36.59 | 36.46 | 36.34 | 39 |
| 40 | 38.45 | 38.32 | 38.18 | 38.05 | 37.92 | 37.79 | 37.66 | 37.53 | 37.40 | 37.27 | 40 |
| 41 | 39.41 | 39.28 | 39.14 | 39.00 | 38.87 | 38.73 | 38.60 | 38.47 | 38.34 | 38.20 | 41 |
| 42 | 40.37 | 40.24 | 40.09 | 39.95 | 39.82 | 39.68 | 39.54 | 39.41 | 39.27 | 39.13 | 42 |
| 43 | 41.33 | 41.19 | 41.05 | 40.90 | 40.76 | 40.62 | 40.48 | 40.35 | 40.21 | 40.07 | 43 |
| 44 | 42.30 | 42.15 | 42.00 | 41.86 | 41.71 | 41.57 | 41.43 | 41.28 | 41.14 | 41.00 | 44 |
| 45 | 43.26 | 43.11 | 42.95 | 42.81 | 42.66 | 42.51 | 42.37 | 42.22 | 42.08 | 41.93 | 45 |
| 46 | 44.23 | 44.07 | 43.91 | 43.76 | 43.61 | 43.46 | 43.31 | 43.16 | 43.01 | 42.86 | 46 |
| 47 | 45.18 | 45.03 | 44.86 | 44.71 | 44.56 | 44.40 | 44.25 | 44.10 | 43.94 | 43.79 | 47 |
| 48 | 46.14 | 45.98 | 45.82 | 45.66 | 45.50 | 45.35 | 45.19 | 45.04 | 44.88 | 44.73 | 48 |
| 49 | 47.10 | 46.94 | 46.77 | 46.61 | 46.45 | 46.29 | 46.13 | 45.97 | 45.81 | 45.65 | 49 |
| 50 | 48.07 | 47.90 | 47.73 | 47.57 | 47.40 | 47.24 | 47.07 | 46.91 | 46.75 | 46.59 | 50 |

REDUCTION OF THE VOLUME OF GASES 23

Continued.

gases to a temperature of 0° C.—*Continued.*

| 0°. | 11°. | 12°. | 13°. | 14°. | 15°. | 16°. | 17°. | 18°. | 19°. | 20°. | 0°. |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 51 | 49.08 | 48.86 | 48.69 | 48.52 | 48.85 | 48.18 | 48.01 | 47.85 | 47.68 | 47.52 | 51 |
| 52 | 49.99 | 49.82 | 49.64 | 49.47 | 49.80 | 49.13 | 48.95 | 48.79 | 48.62 | 48.45 | 52 |
| 53 | 50.95 | 50.77 | 50.59 | 50.42 | 50.24 | 50.07 | 49.89 | 49.72 | 49.55 | 49.38 | 53 |
| 54 | 51.91 | 51.73 | 51.55 | 51.37 | 51.19 | 51.02 | 50.84 | 50.66 | 50.49 | 50.32 | 54 |
| 55 | 52.87 | 52.69 | 52.50 | 52.33 | 52.14 | 51.96 | 51.78 | 51.60 | 51.43 | 51.25 | 55 |
| 56 | 53.84 | 53.65 | 53.46 | 53.28 | 53.09 | 52.91 | 52.72 | 52.54 | 52.36 | 52.18 | 56 |
| 57 | 54.80 | 54.61 | 54.41 | 54.23 | 54.04 | 53.86 | 53.68 | 53.48 | 53.29 | 53.11 | 57 |
| 58 | 55.76 | 55.56 | 55.37 | 55.18 | 54.98 | 54.80 | 54.60 | 54.42 | 54.23 | 54.04 | 58 |
| 59 | 56.72 | 56.52 | 56.32 | 56.13 | 55.93 | 55.74 | 55.54 | 55.35 | 55.16 | 54.97 | 59 |
| 60 | 57.68 | 57.47 | 57.28 | 57.08 | 56.88 | 56.68 | 56.48 | 56.29 | 56.09 | 55.91 | 60 |
| 61 | 58.64 | 58.43 | 58.23 | 58.03 | 57.83 | 57.63 | 57.42 | 57.23 | 57.02 | 56.84 | 61 |
| 62 | 59.60 | 59.39 | 59.19 | 58.98 | 58.78 | 58.57 | 58.36 | 58.17 | 57.96 | 57.77 | 62 |
| 63 | 60.56 | 60.35 | 60.14 | 59.93 | 59.72 | 59.52 | 59.30 | 59.11 | 58.90 | 58.71 | 63 |
| 64 | 61.53 | 61.31 | 61.10 | 60.88 | 60.67 | 60.46 | 60.25 | 60.04 | 59.83 | 59.64 | 64 |
| 65 | 62.49 | 62.28 | 62.05 | 61.84 | 61.62 | 61.40 | 61.19 | 60.98 | 60.77 | 60.57 | 65 |
| 66 | 63.45 | 63.22 | 63.01 | 62.79 | 62.57 | 62.35 | 62.13 | 61.92 | 61.70 | 61.50 | 66 |
| 67 | 64.41 | 64.18 | 63.96 | 63.74 | 63.52 | 63.29 | 63.07 | 62.85 | 62.63 | 62.43 | 67 |
| 68 | 65.37 | 65.13 | 64.92 | 64.69 | 64.46 | 64.23 | 64.01 | 63.80 | 63.57 | 63.36 | 68 |
| 69 | 66.33 | 66.09 | 65.87 | 65.64 | 65.41 | 65.18 | 64.95 | 64.73 | 64.50 | 64.30 | 69 |
| 70 | 67.29 | 67.05 | 66.82 | 66.59 | 66.36 | 66.13 | 65.90 | 65.67 | 65.44 | 65.23 | 70 |
| 71 | 68.25 | 68.01 | 67.77 | 67.54 | 67.31 | 67.07 | 66.84 | 66.61 | 66.38 | 66.16 | 71 |
| 72 | 69.21 | 68.97 | 68.73 | 68.49 | 68.26 | 68.02 | 67.78 | 67.55 | 67.31 | 67.09 | 72 |
| 73 | 70.17 | 69.92 | 69.68 | 69.44 | 69.20 | 68.96 | 68.72 | 68.49 | 68.25 | 68.03 | 73 |
| 74 | 71.14 | 70.88 | 70.64 | 70.40 | 70.15 | 69.91 | 69.66 | 69.42 | 69.18 | 68.96 | 74 |
| 75 | 72.10 | 71.84 | 71.59 | 71.35 | 71.10 | 70.85 | 70.61 | 70.37 | 70.12 | 69.90 | 75 |
| 76 | 73.06 | 72.80 | 72.55 | 72.30 | 72.05 | 71.80 | 71.55 | 71.30 | 71.05 | 70.82 | 76 |
| 77 | 74.02 | 73.76 | 73.51 | 73.25 | 73.00 | 72.74 | 72.49 | 72.24 | 71.98 | 71.75 | 77 |
| 78 | 74.98 | 74.71 | 74.46 | 74.20 | 73.94 | 73.69 | 73.43 | 73.18 | 72.92 | 72.68 | 78 |
| 79 | 75.94 | 75.67 | 75.41 | 75.15 | 74.89 | 74.63 | 74.37 | 74.11 | 73.85 | 73.61 | 79 |
| 80 | 76.90 | 76.63 | 76.37 | 76.10 | 75.84 | 75.58 | 75.31 | 75.06 | 74.79 | 74.54 | 80 |
| 81 | 77.86 | 77.59 | 77.32 | 77.05 | 76.79 | 76.52 | 76.25 | 76.00 | 75.73 | 75.47 | 81 |
| 82 | 78.82 | 78.55 | 78.28 | 78.00 | 77.74 | 77.47 | 77.19 | 76.94 | 76.66 | 76.40 | 82 |
| 83 | 79.78 | 79.50 | 79.23 | 78.95 | 78.68 | 78.41 | 78.13 | 77.87 | 77.60 | 77.34 | 83 |
| 84 | 80.75 | 80.46 | 80.19 | 79.91 | 79.63 | 79.35 | 79.08 | 78.81 | 78.53 | 78.27 | 84 |
| 85 | 81.71 | 81.42 | 81.14 | 80.86 | 80.58 | 80.30 | 80.02 | 79.75 | 79.47 | 79.20 | 85 |
| 86 | 82.67 | 82.38 | 82.10 | 81.81 | 81.53 | 81.24 | 80.96 | 80.69 | 80.40 | 80.13 | 86 |
| 87 | 83.63 | 83.33 | 83.05 | 82.76 | 82.48 | 82.19 | 81.90 | 81.63 | 81.33 | 81.06 | 87 |
| 88 | 84.59 | 84.29 | 84.01 | 83.71 | 83.42 | 83.13 | 82.84 | 82.57 | 82.27 | 81.99 | 88 |
| 89 | 85.56 | 85.25 | 84.96 | 84.66 | 84.37 | 84.08 | 83.78 | 83.50 | 83.22 | 82.93 | 89 |
| 90 | 86.52 | 86.21 | 85.92 | 85.62 | 85.32 | 85.02 | 84.72 | 84.44 | 84.14 | 83.85 | 90 |
| 91 | 87.48 | 87.17 | 86.87 | 86.57 | 86.27 | 85.96 | 85.66 | 85.38 | 85.07 | 84.79 | 91 |
| 92 | 88.44 | 88.13 | 87.83 | 87.52 | 87.22 | 86.91 | 86.60 | 86.32 | 86.01 | 85.72 | 92 |
| 93 | 89.40 | 89.09 | 88.78 | 88.47 | 88.16 | 87.85 | 87.54 | 87.25 | 86.95 | 86.66 | 93 |
| 94 | 90.36 | 90.04 | 89.73 | 89.42 | 89.11 | 88.80 | 88.49 | 88.19 | 87.88 | 87.59 | 94 |
| 95 | 91.33 | 91.01 | 90.69 | 90.38 | 90.06 | 89.74 | 89.43 | 89.13 | 88.82 | 88.52 | 95 |
| 96 | 92.29 | 91.96 | 91.64 | 91.33 | 91.01 | 90.69 | 90.37 | 90.07 | 89.75 | 89.45 | 96 |
| 97 | 93.25 | 92.92 | 92.59 | 92.28 | 91.96 | 91.63 | 91.31 | 91.00 | 90.68 | 90.38 | 97 |
| 98 | 94.21 | 93.87 | 93.55 | 93.23 | 92.90 | 92.58 | 92.25 | 91.94 | 91.62 | 91.31 | 98 |
| 99 | 95.17 | 94.83 | 94.50 | 94.18 | 93.85 | 93.53 | 93.19 | 92.88 | 92.55 | 92.24 | 99 |
| 100 | 96.13 | 95.79 | 95.46 | 95.13 | 94.80 | 94.47 | 94.14 | 93.82 | 93.49 | 93.18 | 100 |

TABLE 12—

I. Table for reducing the volumes of

| 0°. | 21°. | 22°. | 23°. | 24°. | 25°. | 26°. | 27°. | 28°. | 29°. | 0°. |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1 | 0.929 | 0.926 | 0.922 | 0.919 | 0.916 | 0.913 | 0.910 | 0.907 | 0.904 | 1 |
| 2 | 1.857 | 1.851 | 1.845 | 1.839 | 1.832 | 1.826 | 1.820 | 1.814 | 1.808 | 2 |
| 3 | 2.786 | 2.777 | 2.767 | 2.758 | 2.749 | 2.739 | 2.730 | 2.721 | 2.712 | 3 |
| 4 | 3.714 | 3.702 | 3.690 | 3.677 | 3.665 | 3.652 | 3.640 | 3.628 | 3.616 | 4 |
| 5 | 4.643 | 4.628 | 4.612 | 4.597 | 4.581 | 4.566 | 4.551 | 4.535 | 4.520 | 5 |
| 6 | 5.572 | 5.553 | 5.534 | 5.516 | 5.497 | 5.479 | 5.461 | 5.442 | 5.424 | 6 |
| 7 | 6.500 | 6.479 | 6.457 | 6.435 | 6.413 | 6.392 | 6.371 | 6.349 | 6.328 | 7 |
| 8 | 7.429 | 7.404 | 7.379 | 7.354 | 7.330 | 7.305 | 7.281 | 7.256 | 7.232 | 8 |
| 9 | 8.357 | 8.330 | 8.302 | 8.274 | 8.246 | 8.218 | 8.191 | 8.168 | 8.135 | 9 |
| 10 | 9.286 | 9.255 | 9.224 | 9.193 | 9.162 | 9.131 | 9.101 | 9.070 | 9.040 | 10 |
| 11 | 10.21 | 10.18 | 10.15 | 10.11 | 10.07 | 10.04 | 10.01 | 9.98 | 9.94 | 11 |
| 12 | 11.14 | 11.11 | 11.07 | 11.03 | 10.99 | 10.96 | 10.92 | 10.88 | 10.85 | 12 |
| 13 | 12.07 | 12.03 | 11.99 | 11.95 | 11.91 | 11.87 | 11.83 | 11.79 | 11.75 | 13 |
| 14 | 13.00 | 12.96 | 12.91 | 12.87 | 12.83 | 12.78 | 12.74 | 12.70 | 12.66 | 14 |
| 15 | 13.93 | 13.88 | 13.84 | 13.79 | 13.74 | 13.70 | 13.65 | 13.61 | 13.56 | 15 |
| 16 | 14.86 | 14.81 | 14.76 | 14.71 | 14.66 | 14.61 | 14.56 | 14.51 | 14.46 | 16 |
| 17 | 15.79 | 15.73 | 15.68 | 15.63 | 15.58 | 15.52 | 15.47 | 15.42 | 15.37 | 17 |
| 18 | 16.71 | 16.66 | 16.60 | 16.55 | 16.49 | 16.44 | 16.38 | 16.33 | 16.27 | 18 |
| 19 | 17.64 | 17.58 | 17.53 | 17.47 | 17.41 | 17.35 | 17.29 | 17.23 | 17.18 | 19 |
| 20 | 18.57 | 18.51 | 18.45 | 18.39 | 18.32 | 18.26 | 18.20 | 18.14 | 18.08 | 20 |
| 21 | 19.50 | 19.43 | 19.37 | 19.31 | 19.24 | 19.17 | 19.11 | 19.05 | 18.98 | 21 |
| 22 | 20.43 | 20.36 | 20.29 | 20.23 | 20.16 | 20.09 | 20.02 | 19.95 | 19.89 | 22 |
| 23 | 21.36 | 21.29 | 21.21 | 21.15 | 21.07 | 21.00 | 20.93 | 20.86 | 20.79 | 23 |
| 24 | 22.28 | 22.21 | 22.14 | 22.07 | 21.99 | 21.91 | 21.84 | 21.77 | 21.70 | 24 |
| 25 | 23.21 | 23.14 | 23.06 | 22.99 | 22.90 | 22.83 | 22.75 | 22.68 | 22.60 | 25 |
| 26 | 24.14 | 24.06 | 23.98 | 23.91 | 23.82 | 23.74 | 23.66 | 23.58 | 23.50 | 26 |
| 27 | 25.07 | 24.99 | 24.90 | 24.83 | 24.75 | 24.66 | 24.57 | 24.49 | 24.41 | 27 |
| 28 | 26.00 | 25.91 | 25.82 | 25.74 | 25.65 | 25.57 | 25.48 | 25.40 | 25.31 | 28 |
| 29 | 26.93 | 26.84 | 26.75 | 26.67 | 26.57 | 26.48 | 26.39 | 26.30 | 26.22 | 29 |
| 30 | 27.86 | 27.77 | 27.67 | 27.58 | 27.49 | 27.39 | 27.30 | 27.21 | 27.12 | 30 |
| 31 | 28.79 | 28.70 | 28.59 | 28.50 | 28.41 | 28.30 | 28.21 | 28.12 | 28.02 | 31 |
| 32 | 29.72 | 29.62 | 29.51 | 29.42 | 29.32 | 29.22 | 29.12 | 29.02 | 28.93 | 32 |
| 33 | 30.65 | 30.55 | 30.44 | 30.34 | 30.24 | 30.13 | 30.03 | 29.93 | 29.83 | 33 |
| 34 | 31.57 | 31.47 | 31.36 | 31.26 | 31.16 | 31.04 | 30.94 | 30.84 | 30.74 | 34 |
| 35 | 32.50 | 32.40 | 32.28 | 32.18 | 32.07 | 31.96 | 31.85 | 31.75 | 31.64 | 35 |
| 36 | 33.43 | 33.32 | 33.20 | 33.10 | 32.99 | 32.87 | 32.76 | 32.65 | 32.54 | 36 |
| 37 | 34.36 | 34.25 | 34.12 | 34.02 | 33.90 | 33.78 | 33.67 | 33.56 | 33.45 | 37 |
| 38 | 35.29 | 35.17 | 35.05 | 34.93 | 34.82 | 34.70 | 34.58 | 34.47 | 34.35 | 38 |
| 39 | 36.22 | 36.10 | 35.97 | 35.85 | 35.74 | 35.61 | 35.49 | 35.37 | 35.26 | 39 |
| 40 | 37.14 | 37.02 | 36.90 | 36.77 | 36.65 | 36.52 | 36.40 | 36.28 | 36.16 | 40 |
| 41 | 38.07 | 37.95 | 37.82 | 37.69 | 37.57 | 37.43 | 37.31 | 37.19 | 37.06 | 41 |
| 42 | 39.00 | 38.87 | 38.74 | 38.61 | 38.48 | 38.35 | 38.22 | 38.09 | 37.97 | 42 |
| 43 | 39.93 | 39.80 | 39.66 | 39.53 | 39.40 | 39.26 | 39.13 | 39.00 | 38.87 | 43 |
| 44 | 40.86 | 40.72 | 40.59 | 40.45 | 40.32 | 40.17 | 40.04 | 39.91 | 39.78 | 44 |
| 45 | 41.78 | 41.65 | 41.51 | 41.37 | 41.23 | 41.09 | 40.95 | 40.82 | 40.68 | 45 |
| 46 | 42.71 | 42.57 | 42.43 | 42.29 | 42.15 | 42.00 | 41.86 | 41.73 | 41.58 | 46 |
| 47 | 43.64 | 43.50 | 43.35 | 43.21 | 43.06 | 42.91 | 42.77 | 42.63 | 42.49 | 47 |
| 48 | 44.57 | 44.42 | 44.27 | 44.12 | 43.98 | 43.83 | 43.68 | 43.54 | 43.39 | 48 |
| 49 | 45.50 | 45.35 | 45.19 | 45.04 | 44.89 | 44.74 | 44.59 | 44.44 | 44.30 | 49 |
| 50 | 46.43 | 46.28 | 46.12 | 45.97 | 45.81 | 45.66 | 45.51 | 45.35 | 45.20 | 50 |

*Continued.*gases to a temperature of 0° C.—*Continued.*

| 0°. | 21°. | 22°. | 23°. | 24°. | 25°. | 26°. | 27°. | 28°. | 29°. | 0°. |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 51 | 47·86 | 47·20 | 47·04 | 46·89 | 46·78 | 46·57 | 46·42 | 46·26 | 46·10 | 51 |
| 52 | 48·29 | 48·18 | 47·96 | 47·81 | 47·64 | 47·49 | 47·38 | 47·16 | 47·01 | 52 |
| 53 | 49·22 | 49·06 | 48·89 | 48·73 | 48·56 | 48·40 | 48·24 | 48·07 | 47·91 | 53 |
| 54 | 50·14 | 49·98 | 49·81 | 49·65 | 49·48 | 49·31 | 49·15 | 48·98 | 48·82 | 54 |
| 55 | 51·07 | 50·91 | 50·73 | 50·57 | 50·39 | 50·28 | 50·06 | 49·89 | 49·72 | 55 |
| 56 | 52·00 | 51·83 | 51·65 | 51·49 | 51·31 | 51·14 | 50·97 | 50·79 | 50·62 | 56 |
| 57 | 52·93 | 52·76 | 52·58 | 52·41 | 52·22 | 52·05 | 51·88 | 51·70 | 51·53 | 57 |
| 58 | 53·86 | 53·68 | 53·50 | 53·32 | 53·14 | 52·97 | 52·79 | 52·61 | 52·43 | 58 |
| 59 | 54·79 | 54·61 | 54·42 | 54·24 | 54·06 | 53·88 | 53·70 | 53·51 | 53·34 | 59 |
| 60 | 55·72 | 55·53 | 55·34 | 55·16 | 54·97 | 54·79 | 54·61 | 54·42 | 54·24 | 60 |
| 61 | 56·65 | 56·46 | 56·26 | 56·08 | 55·89 | 55·70 | 55·52 | 55·33 | 55·14 | 61 |
| 62 | 57·58 | 57·38 | 57·19 | 57·00 | 56·80 | 56·62 | 56·43 | 56·23 | 56·05 | 62 |
| 63 | 58·51 | 58·31 | 58·11 | 57·92 | 57·72 | 57·53 | 57·34 | 57·14 | 56·95 | 63 |
| 64 | 59·42 | 59·23 | 59·03 | 58·84 | 58·64 | 58·44 | 58·25 | 58·05 | 57·86 | 64 |
| 65 | 60·36 | 60·16 | 59·95 | 59·76 | 59·55 | 59·36 | 59·16 | 58·96 | 58·76 | 65 |
| 66 | 61·29 | 61·08 | 60·87 | 60·68 | 60·47 | 60·27 | 60·07 | 59·86 | 59·66 | 66 |
| 67 | 62·22 | 62·01 | 61·79 | 61·60 | 61·38 | 61·18 | 60·98 | 60·77 | 60·57 | 67 |
| 68 | 63·15 | 62·93 | 62·72 | 62·51 | 62·30 | 62·10 | 61·89 | 61·68 | 61·47 | 68 |
| 69 | 64·08 | 63·86 | 63·64 | 63·43 | 63·22 | 63·01 | 62·80 | 62·58 | 62·38 | 69 |
| 70 | 65·00 | 64·79 | 64·57 | 64·35 | 64·13 | 63·92 | 63·71 | 63·49 | 63·28 | 70 |
| 71 | 65·93 | 65·71 | 65·49 | 65·27 | 65·05 | 64·83 | 64·62 | 64·40 | 64·18 | 71 |
| 72 | 66·86 | 66·64 | 66·42 | 66·19 | 65·96 | 65·75 | 65·53 | 65·30 | 65·09 | 72 |
| 73 | 67·79 | 67·57 | 67·34 | 67·11 | 66·88 | 66·66 | 66·44 | 66·21 | 65·99 | 73 |
| 74 | 68·61 | 68·40 | 68·26 | 68·03 | 67·80 | 67·57 | 67·35 | 67·12 | 66·90 | 74 |
| 75 | 69·64 | 69·42 | 69·18 | 68·95 | 68·71 | 68·49 | 68·26 | 68·03 | 67·80 | 75 |
| 76 | 70·57 | 70·34 | 70·10 | 69·87 | 69·63 | 69·40 | 69·17 | 68·93 | 68·70 | 76 |
| 77 | 71·50 | 71·27 | 71·03 | 70·79 | 70·54 | 70·31 | 70·08 | 69·84 | 69·61 | 77 |
| 78 | 72·43 | 72·19 | 71·95 | 71·70 | 71·46 | 71·22 | 70·99 | 70·75 | 70·51 | 78 |
| 79 | 73·36 | 73·12 | 72·87 | 72·62 | 72·38 | 72·14 | 71·90 | 71·65 | 71·42 | 79 |
| 80 | 74·29 | 74·04 | 73·79 | 73·54 | 73·30 | 73·05 | 72·81 | 72·56 | 72·32 | 80 |
| 81 | 75·22 | 74·97 | 74·71 | 74·46 | 74·22 | 73·96 | 73·72 | 73·47 | 73·22 | 81 |
| 82 | 76·15 | 75·89 | 75·63 | 75·38 | 75·13 | 74·88 | 74·63 | 74·37 | 74·13 | 82 |
| 83 | 77·08 | 76·82 | 76·56 | 76·30 | 76·05 | 75·79 | 75·54 | 75·28 | 75·03 | 83 |
| 84 | 78·00 | 77·74 | 77·48 | 77·22 | 76·96 | 76·70 | 76·45 | 76·19 | 75·94 | 84 |
| 85 | 78·93 | 78·67 | 78·40 | 78·14 | 77·88 | 77·62 | 77·36 | 77·10 | 76·84 | 85 |
| 86 | 79·86 | 79·59 | 79·32 | 79·06 | 78·80 | 78·53 | 78·27 | 78·00 | 77·74 | 86 |
| 87 | 80·79 | 80·52 | 80·25 | 79·98 | 79·71 | 79·44 | 79·17 | 78·91 | 78·65 | 87 |
| 88 | 81·72 | 81·44 | 81·17 | 80·90 | 80·63 | 80·36 | 80·09 | 79·82 | 79·56 | 88 |
| 89 | 82·65 | 82·37 | 82·09 | 81·82 | 81·55 | 81·27 | 81·00 | 80·72 | 80·46 | 89 |
| 90 | 83·57 | 83·30 | 83·02 | 82·74 | 82·46 | 82·18 | 81·91 | 81·63 | 81·36 | 90 |
| 91 | 84·50 | 84·22 | 83·94 | 83·66 | 83·38 | 83·09 | 82·82 | 82·54 | 82·26 | 91 |
| 92 | 85·43 | 85·15 | 84·86 | 84·58 | 84·29 | 84·01 | 83·73 | 83·44 | 83·17 | 92 |
| 93 | 86·36 | 86·08 | 85·79 | 85·50 | 85·21 | 84·92 | 84·64 | 84·35 | 84·07 | 93 |
| 94 | 87·28 | 87·00 | 86·71 | 86·42 | 86·13 | 85·85 | 85·56 | 85·26 | 84·98 | 94 |
| 95 | 88·21 | 87·93 | 87·63 | 87·34 | 87·04 | 86·75 | 86·46 | 86·17 | 85·88 | 95 |
| 96 | 89·14 | 88·85 | 88·55 | 88·26 | 87·96 | 87·66 | 87·37 | 87·07 | 86·78 | 96 |
| 97 | 90·07 | 89·78 | 89·48 | 89·18 | 88·87 | 88·57 | 88·28 | 87·98 | 87·69 | 97 |
| 98 | 91·00 | 90·70 | 90·40 | 90·09 | 89·79 | 89·48 | 89·19 | 88·89 | 88·59 | 98 |
| 99 | 91·93 | 91·63 | 91·32 | 91·01 | 90·71 | 90·40 | 90·10 | 89·79 | 89·50 | 99 |
| 100 | 92·86 | 92·55 | 92·24 | 91·93 | 91·62 | 91·31 | 91·01 | 90·70 | 90·40 | 100 |

TABLE 12—Continued. II. Table for reducing the

Deduct from the barometric pressure 1 mm. for temperature between 0° and 12°
for the expansion

| 700 | 710 | 712 | 714 | 716 | 718 | 720 | 722 | 724 | 726 | 728 | 760 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1 | 0.984 | 0.987 | 0.940 | 0.942 | 0.945 | 0.947 | 0.950 | 0.953 | 0.955 | 0.958 | 1 |
| 2 | 1.968 | 1.874 | 1.879 | 1.884 | 1.890 | 1.895 | 1.900 | 1.905 | 1.911 | 1.916 | 2 |
| 3 | 2.803 | 2.810 | 2.818 | 2.826 | 2.834 | 2.842 | 2.850 | 2.858 | 2.866 | 2.874 | 3 |
| 4 | 3.788 | 3.747 | 3.753 | 3.768 | 3.779 | 3.789 | 3.800 | 3.810 | 3.821 | 3.832 | 4 |
| 5 | 4.672 | 4.685 | 4.697 | 4.711 | 4.724 | 4.736 | 4.750 | 4.763 | 4.777 | 4.790 | 5 |
| 6 | 5.607 | 5.621 | 5.637 | 5.653 | 5.669 | 5.684 | 5.700 | 5.716 | 5.732 | 5.747 | 6 |
| 7 | 6.540 | 6.558 | 6.577 | 6.595 | 6.614 | 6.631 | 6.650 | 6.668 | 6.687 | 6.705 | 7 |
| 8 | 7.474 | 7.494 | 7.516 | 7.537 | 7.558 | 7.578 | 7.600 | 7.621 | 7.642 | 7.663 | 8 |
| 9 | 8.409 | 8.431 | 8.456 | 8.479 | 8.503 | 8.526 | 8.550 | 8.573 | 8.598 | 8.621 | 9 |
| 10 | 9.34 | 9.37 | 9.40 | 9.42 | 9.45 | 9.47 | 9.50 | 9.53 | 9.55 | 9.58 | 10 |
| 11 | 10.23 | 10.31 | 10.34 | 10.36 | 10.39 | 10.42 | 10.45 | 10.48 | 10.51 | 10.54 | 11 |
| 12 | 11.21 | 11.24 | 11.27 | 11.30 | 11.34 | 11.37 | 11.40 | 11.43 | 11.46 | 11.50 | 12 |
| 13 | 12.14 | 12.18 | 12.21 | 12.24 | 12.28 | 12.31 | 12.35 | 12.38 | 12.41 | 12.45 | 13 |
| 14 | 13.08 | 13.12 | 13.16 | 13.19 | 13.23 | 13.26 | 13.30 | 13.34 | 13.37 | 13.41 | 14 |
| 15 | 14.02 | 14.06 | 14.10 | 14.13 | 14.17 | 14.21 | 14.25 | 14.29 | 14.33 | 14.37 | 15 |
| 16 | 14.95 | 14.99 | 15.03 | 15.07 | 15.11 | 15.15 | 15.20 | 15.24 | 15.28 | 15.33 | 16 |
| 17 | 15.88 | 15.93 | 15.98 | 16.02 | 16.06 | 16.10 | 16.15 | 16.19 | 16.23 | 16.28 | 17 |
| 18 | 16.82 | 16.87 | 16.92 | 16.96 | 17.01 | 17.05 | 17.10 | 17.15 | 17.19 | 17.24 | 18 |
| 19 | 17.76 | 17.81 | 17.86 | 17.90 | 17.95 | 18.00 | 18.05 | 18.10 | 18.15 | 18.21 | 19 |
| 20 | 18.68 | 18.74 | 18.79 | 18.84 | 18.90 | 18.95 | 19.00 | 19.05 | 19.11 | 19.16 | 20 |
| 21 | 19.62 | 19.68 | 19.73 | 19.78 | 19.84 | 19.90 | 19.95 | 20.00 | 20.06 | 20.12 | 21 |
| 22 | 20.55 | 20.61 | 20.67 | 20.72 | 20.78 | 20.84 | 20.90 | 20.96 | 21.01 | 21.07 | 22 |
| 23 | 21.49 | 21.55 | 21.61 | 21.66 | 21.73 | 21.79 | 21.85 | 21.91 | 21.97 | 22.03 | 23 |
| 24 | 22.43 | 22.49 | 22.55 | 22.61 | 22.68 | 22.74 | 22.80 | 22.86 | 22.92 | 22.99 | 24 |
| 25 | 23.35 | 23.42 | 23.49 | 23.55 | 23.62 | 23.69 | 23.75 | 23.81 | 23.88 | 23.95 | 25 |
| 26 | 24.29 | 24.36 | 24.43 | 24.50 | 24.57 | 24.64 | 24.70 | 24.77 | 24.83 | 24.90 | 26 |
| 27 | 25.23 | 25.30 | 25.37 | 25.44 | 25.51 | 25.58 | 25.65 | 25.72 | 25.79 | 25.86 | 27 |
| 28 | 26.16 | 26.23 | 26.30 | 26.37 | 26.45 | 26.52 | 26.60 | 26.67 | 26.74 | 26.82 | 28 |
| 29 | 27.10 | 27.17 | 27.24 | 27.31 | 27.40 | 27.48 | 27.55 | 27.62 | 27.70 | 27.78 | 29 |
| 30 | 28.03 | 28.10 | 28.18 | 28.26 | 28.34 | 28.42 | 28.50 | 28.58 | 28.66 | 28.74 | 30 |
| 31 | 28.97 | 29.04 | 29.12 | 29.20 | 29.29 | 29.37 | 29.45 | 29.53 | 29.62 | 29.70 | 31 |
| 32 | 29.90 | 29.98 | 30.06 | 30.14 | 30.23 | 30.32 | 30.40 | 30.48 | 30.57 | 30.66 | 32 |
| 33 | 30.83 | 30.91 | 31.00 | 31.08 | 31.17 | 31.26 | 31.35 | 31.43 | 31.52 | 31.61 | 33 |
| 34 | 31.77 | 31.85 | 31.94 | 32.03 | 32.12 | 32.21 | 32.30 | 32.39 | 32.48 | 32.57 | 34 |
| 35 | 32.71 | 32.79 | 32.88 | 32.97 | 33.07 | 33.16 | 33.25 | 33.34 | 33.44 | 33.53 | 35 |
| 36 | 33.64 | 33.73 | 33.82 | 33.91 | 34.01 | 34.10 | 34.20 | 34.29 | 34.39 | 34.49 | 36 |
| 37 | 34.67 | 34.76 | 34.86 | 34.96 | 35.05 | 35.15 | 35.25 | 35.35 | 35.45 | 35.55 | 37 |
| 38 | 35.60 | 35.69 | 35.79 | 35.89 | 35.99 | 36.09 | 36.19 | 36.29 | 36.39 | 36.49 | 38 |
| 39 | 36.64 | 36.74 | 36.84 | 36.94 | 37.05 | 37.15 | 37.25 | 37.35 | 37.45 | 37.55 | 39 |
| 40 | 37.68 | 37.78 | 37.88 | 37.98 | 38.09 | 38.19 | 38.29 | 38.39 | 38.49 | 38.59 | 40 |
| 41 | 38.81 | 38.91 | 39.01 | 39.11 | 39.21 | 39.31 | 39.41 | 39.51 | 39.61 | 39.71 | 41 |
| 42 | 39.28 | 39.38 | 39.48 | 39.58 | 39.68 | 39.78 | 39.88 | 39.98 | 40.08 | 40.18 | 42 |
| 43 | 40.13 | 40.23 | 40.33 | 40.43 | 40.53 | 40.63 | 40.73 | 40.83 | 40.93 | 41.03 | 43 |
| 44 | 41.11 | 41.21 | 41.31 | 41.41 | 41.51 | 41.61 | 41.71 | 41.81 | 41.91 | 42.01 | 44 |
| 45 | 42.05 | 42.15 | 42.25 | 42.35 | 42.45 | 42.55 | 42.65 | 42.75 | 42.85 | 42.95 | 45 |
| 46 | 42.98 | 43.08 | 43.18 | 43.28 | 43.38 | 43.48 | 43.58 | 43.68 | 43.78 | 43.88 | 46 |
| 47 | 43.91 | 44.01 | 44.11 | 44.21 | 44.31 | 44.41 | 44.51 | 44.61 | 44.71 | 44.81 | 47 |
| 48 | 44.84 | 44.94 | 45.04 | 45.14 | 45.24 | 45.34 | 45.44 | 45.54 | 45.64 | 45.74 | 48 |
| 49 | 45.78 | 45.88 | 45.98 | 46.08 | 46.18 | 46.28 | 46.38 | 46.48 | 46.58 | 46.68 | 49 |
| 50 | 46.73 | 46.83 | 46.93 | 47.03 | 47.13 | 47.23 | 47.33 | 47.43 | 47.53 | 47.63 | 50 |

volumes of gases to a pressure of 760 mm.

C., and 2 mm. between 18° and 19° C., 3 mm. between 20° and 25° C., to compensate of mercury.

| 760 | 710 | 712 | 714 | 716 | 718 | 720 | 722 | 724 | 726 | 728 | 760 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 51 | 47.65 | 47.79 | 47.92 | 48.05 | 48.18 | 48.31 | 48.45 | 48.59 | 48.78 | 48.80 | 51 |
| 52 | 48.58 | 48.72 | 48.85 | 48.99 | 49.13 | 49.26 | 49.40 | 49.54 | 49.68 | 49.82 | 52 |
| 53 | 49.62 | 49.66 | 49.70 | 49.93 | 50.07 | 50.21 | 50.35 | 50.48 | 50.64 | 50.78 | 53 |
| 54 | 50.45 | 50.59 | 50.78 | 50.87 | 51.01 | 51.15 | 51.30 | 51.44 | 51.59 | 51.78 | 54 |
| 55 | 51.88 | 51.58 | 51.07 | 51.82 | 51.96 | 52.10 | 52.25 | 52.39 | 52.54 | 52.69 | 55 |
| 56 | 52.82 | 52.47 | 52.61 | 52.76 | 52.91 | 53.05 | 53.20 | 53.35 | 53.50 | 53.65 | 56 |
| 57 | 53.25 | 53.41 | 53.55 | 53.70 | 53.85 | 54.00 | 54.15 | 54.30 | 54.45 | 54.60 | 57 |
| 58 | 54.19 | 54.84 | 54.49 | 54.64 | 54.79 | 54.94 | 55.10 | 55.25 | 55.41 | 55.56 | 58 |
| 59 | 55.18 | 55.23 | 55.48 | 55.59 | 55.74 | 55.89 | 56.05 | 56.21 | 56.37 | 56.52 | 59 |
| 60 | 56.07 | 56.22 | 56.37 | 56.53 | 56.69 | 56.84 | 57.00 | 57.16 | 57.32 | 57.47 | 60 |
| 61 | 57.00 | 57.15 | 57.31 | 57.47 | 57.63 | 57.79 | 57.95 | 58.11 | 58.27 | 58.43 | 61 |
| 62 | 57.98 | 58.00 | 58.25 | 58.41 | 58.58 | 58.74 | 58.90 | 59.06 | 59.23 | 59.39 | 62 |
| 63 | 58.87 | 59.08 | 59.19 | 59.35 | 59.52 | 59.68 | 59.85 | 60.01 | 60.18 | 60.35 | 63 |
| 64 | 59.80 | 59.96 | 60.13 | 60.30 | 60.47 | 60.63 | 60.80 | 60.97 | 61.14 | 61.30 | 64 |
| 65 | 60.74 | 60.90 | 61.07 | 61.24 | 61.41 | 61.58 | 61.75 | 61.92 | 62.09 | 62.26 | 65 |
| 66 | 61.67 | 61.84 | 62.01 | 62.18 | 62.35 | 62.52 | 62.70 | 62.87 | 63.05 | 63.22 | 66 |
| 67 | 62.60 | 62.77 | 62.95 | 63.12 | 63.30 | 63.47 | 63.65 | 63.82 | 64.00 | 64.18 | 67 |
| 68 | 63.54 | 63.71 | 63.89 | 64.06 | 64.24 | 64.42 | 64.60 | 64.78 | 64.96 | 65.18 | 68 |
| 69 | 64.47 | 64.65 | 64.83 | 65.01 | 65.19 | 65.37 | 65.55 | 65.73 | 65.91 | 66.09 | 69 |
| 70 | 65.40 | 65.58 | 65.77 | 65.95 | 66.14 | 66.32 | 66.50 | 66.68 | 66.87 | 67.05 | 70 |
| 71 | 66.34 | 66.52 | 66.71 | 66.89 | 67.08 | 67.26 | 67.45 | 67.63 | 67.82 | 68.01 | 71 |
| 72 | 67.27 | 67.46 | 67.65 | 67.83 | 68.02 | 68.21 | 68.40 | 68.59 | 68.78 | 68.97 | 72 |
| 73 | 68.20 | 68.39 | 68.58 | 68.77 | 68.97 | 69.16 | 69.35 | 69.54 | 69.73 | 69.92 | 73 |
| 74 | 69.14 | 69.33 | 69.53 | 69.72 | 69.92 | 70.11 | 70.30 | 70.49 | 70.69 | 70.88 | 74 |
| 75 | 70.07 | 70.27 | 70.47 | 70.66 | 70.86 | 71.05 | 71.25 | 71.44 | 71.64 | 71.84 | 75 |
| 76 | 71.01 | 71.21 | 71.41 | 71.60 | 71.80 | 72.00 | 72.20 | 72.40 | 72.60 | 72.80 | 76 |
| 77 | 71.94 | 72.14 | 72.34 | 72.54 | 72.75 | 72.95 | 73.15 | 73.35 | 73.55 | 73.75 | 77 |
| 78 | 72.87 | 73.07 | 73.28 | 73.48 | 73.69 | 73.89 | 74.10 | 74.30 | 74.51 | 74.71 | 78 |
| 79 | 73.80 | 74.01 | 74.22 | 74.42 | 74.63 | 74.84 | 75.05 | 75.25 | 75.46 | 75.67 | 79 |
| 80 | 74.74 | 74.94 | 75.16 | 75.37 | 75.58 | 75.78 | 76.00 | 76.21 | 76.42 | 76.63 | 80 |
| 81 | 75.67 | 75.88 | 76.10 | 76.31 | 76.53 | 76.74 | 76.95 | 77.16 | 77.37 | 77.58 | 81 |
| 82 | 76.60 | 76.82 | 77.04 | 77.25 | 77.47 | 77.68 | 77.90 | 78.11 | 78.33 | 78.54 | 82 |
| 83 | 77.54 | 77.76 | 77.98 | 78.19 | 78.41 | 78.63 | 78.85 | 79.07 | 79.28 | 79.50 | 83 |
| 84 | 78.47 | 78.69 | 78.91 | 79.13 | 79.35 | 79.57 | 79.80 | 80.02 | 80.24 | 80.46 | 84 |
| 85 | 79.41 | 79.63 | 79.86 | 80.08 | 80.31 | 80.53 | 80.75 | 80.97 | 81.19 | 81.41 | 85 |
| 86 | 80.34 | 80.57 | 80.80 | 81.02 | 81.25 | 81.47 | 81.70 | 81.92 | 82.15 | 82.37 | 86 |
| 87 | 81.28 | 81.50 | 81.74 | 81.96 | 82.19 | 82.42 | 82.65 | 82.87 | 83.10 | 83.33 | 87 |
| 88 | 82.21 | 82.44 | 82.68 | 82.90 | 83.13 | 83.36 | 83.60 | 83.83 | 84.06 | 84.29 | 88 |
| 89 | 83.15 | 83.38 | 83.62 | 83.85 | 84.08 | 84.31 | 84.55 | 84.78 | 85.02 | 85.25 | 89 |
| 90 | 84.09 | 84.31 | 84.56 | 84.79 | 85.03 | 85.26 | 85.50 | 85.73 | 85.98 | 86.21 | 90 |
| 91 | 85.02 | 85.25 | 85.50 | 85.73 | 85.98 | 86.21 | 86.45 | 86.69 | 86.93 | 87.17 | 91 |
| 92 | 85.95 | 86.19 | 86.44 | 86.68 | 86.92 | 87.16 | 87.40 | 87.64 | 87.89 | 88.13 | 92 |
| 93 | 86.89 | 87.12 | 87.38 | 87.62 | 87.87 | 88.11 | 88.35 | 88.59 | 88.84 | 89.08 | 93 |
| 94 | 87.82 | 88.06 | 88.32 | 88.56 | 88.81 | 89.05 | 89.30 | 89.54 | 89.80 | 90.04 | 94 |
| 95 | 88.76 | 89.01 | 89.26 | 89.50 | 89.75 | 90.00 | 90.25 | 90.50 | 90.75 | 91.00 | 95 |
| 96 | 89.69 | 89.94 | 90.20 | 90.45 | 90.70 | 90.95 | 91.20 | 91.45 | 91.70 | 91.95 | 96 |
| 97 | 90.62 | 90.87 | 91.13 | 91.38 | 91.64 | 91.89 | 92.15 | 92.40 | 92.66 | 92.91 | 97 |
| 98 | 91.56 | 91.82 | 92.07 | 92.33 | 92.59 | 92.84 | 93.10 | 93.35 | 93.62 | 93.87 | 98 |
| 99 | 92.49 | 92.75 | 93.01 | 93.28 | 93.53 | 93.79 | 94.05 | 94.31 | 94.57 | 94.83 | 99 |
| 100 | 93.42 | 93.68 | 93.95 | 94.21 | 94.47 | 94.74 | 95.00 | 95.26 | 95.53 | 95.79 | 100 |

TABLE 12—Continued. II. Table for reducing the

| 760 | 780 | 792 | 784 | 796 | 798 | 740 | 742 | 744 | 746 | 748 | 760 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1 | 0.961 | 0.963 | 0.966 | 0.968 | 0.971 | 0.974 | 0.976 | 0.979 | 0.982 | 0.984 | 1 |
| 2 | 1.921 | 1.926 | 1.932 | 1.937 | 1.942 | 1.947 | 1.953 | 1.958 | 1.963 | 1.968 | 2 |
| 3 | 2.882 | 2.889 | 2.898 | 2.905 | 2.913 | 2.921 | 2.929 | 2.937 | 2.945 | 2.953 | 3 |
| 4 | 3.842 | 3.852 | 3.864 | 3.874 | 3.884 | 3.895 | 3.905 | 3.916 | 3.926 | 3.937 | 4 |
| 5 | 4.803 | 4.816 | 4.830 | 4.842 | 4.855 | 4.868 | 4.882 | 4.895 | 4.908 | 4.921 | 5 |
| 6 | 5.768 | 5.779 | 5.796 | 5.810 | 5.826 | 5.842 | 5.858 | 5.874 | 5.890 | 5.905 | 6 |
| 7 | 6.724 | 6.742 | 6.762 | 6.779 | 6.797 | 6.816 | 6.834 | 6.853 | 6.871 | 6.889 | 7 |
| 8 | 7.684 | 7.705 | 7.728 | 7.747 | 7.768 | 7.790 | 7.810 | 7.832 | 7.853 | 7.874 | 8 |
| 9 | 8.645 | 8.668 | 8.693 | 8.716 | 8.739 | 8.768 | 8.787 | 8.811 | 8.834 | 8.858 | 9 |
| 10 | 9.61 | 9.63 | 9.66 | 9.68 | 9.71 | 9.74 | 9.76 | 9.79 | 9.82 | 9.84 | 10 |
| 11 | 10.57 | 10.59 | 10.62 | 10.65 | 10.68 | 10.71 | 10.74 | 10.77 | 10.80 | 10.82 | 11 |
| 12 | 11.53 | 11.56 | 11.59 | 11.62 | 11.65 | 11.68 | 11.71 | 11.75 | 11.78 | 11.81 | 12 |
| 13 | 12.49 | 12.52 | 12.55 | 12.59 | 12.62 | 12.66 | 12.69 | 12.73 | 12.76 | 12.79 | 13 |
| 14 | 13.45 | 13.48 | 13.52 | 13.56 | 13.59 | 13.63 | 13.66 | 13.70 | 13.74 | 13.78 | 14 |
| 15 | 14.41 | 14.44 | 14.48 | 14.52 | 14.56 | 14.60 | 14.64 | 14.69 | 14.73 | 14.77 | 15 |
| 16 | 15.37 | 15.41 | 15.45 | 15.49 | 15.53 | 15.58 | 15.62 | 15.67 | 15.71 | 15.75 | 16 |
| 17 | 16.33 | 16.37 | 16.41 | 16.46 | 16.50 | 16.55 | 16.60 | 16.65 | 16.69 | 16.73 | 17 |
| 18 | 17.29 | 17.33 | 17.38 | 17.43 | 17.47 | 17.52 | 17.57 | 17.62 | 17.67 | 17.72 | 18 |
| 19 | 18.25 | 18.29 | 18.35 | 18.40 | 18.45 | 18.50 | 18.55 | 18.60 | 18.65 | 18.70 | 19 |
| 20 | 19.21 | 19.26 | 19.32 | 19.37 | 19.42 | 19.47 | 19.53 | 19.58 | 19.63 | 19.68 | 20 |
| 21 | 20.17 | 20.22 | 20.28 | 20.34 | 20.39 | 20.44 | 20.50 | 20.56 | 20.61 | 20.66 | 21 |
| 22 | 21.13 | 21.19 | 21.25 | 21.31 | 21.36 | 21.42 | 21.48 | 21.54 | 21.59 | 21.65 | 22 |
| 23 | 22.09 | 22.15 | 22.21 | 22.27 | 22.33 | 22.39 | 22.45 | 22.51 | 22.57 | 22.64 | 23 |
| 24 | 23.05 | 23.11 | 23.18 | 23.24 | 23.30 | 23.36 | 23.43 | 23.50 | 23.56 | 23.63 | 24 |
| 25 | 24.01 | 24.07 | 24.14 | 24.21 | 24.27 | 24.34 | 24.41 | 24.48 | 24.54 | 24.61 | 25 |
| 26 | 24.97 | 25.04 | 25.11 | 25.18 | 25.24 | 25.31 | 25.38 | 25.45 | 25.52 | 25.59 | 26 |
| 27 | 25.93 | 26.00 | 26.07 | 26.14 | 26.21 | 26.28 | 26.36 | 26.43 | 26.50 | 26.58 | 27 |
| 28 | 26.89 | 26.96 | 27.04 | 27.12 | 27.18 | 27.26 | 27.33 | 27.41 | 27.48 | 27.56 | 28 |
| 29 | 27.85 | 27.92 | 28.00 | 28.08 | 28.15 | 28.23 | 28.31 | 28.39 | 28.47 | 28.55 | 29 |
| 30 | 28.82 | 28.89 | 28.97 | 29.05 | 29.13 | 29.21 | 29.29 | 29.37 | 29.45 | 29.53 | 30 |
| 31 | 29.78 | 29.86 | 29.94 | 30.02 | 30.10 | 30.18 | 30.26 | 30.35 | 30.43 | 30.51 | 31 |
| 32 | 30.74 | 30.82 | 30.91 | 30.99 | 31.07 | 31.15 | 31.24 | 31.33 | 31.41 | 31.50 | 32 |
| 33 | 31.70 | 31.78 | 31.87 | 31.96 | 32.04 | 32.13 | 32.21 | 32.30 | 32.39 | 32.48 | 33 |
| 34 | 32.66 | 32.75 | 32.84 | 32.93 | 33.01 | 33.10 | 33.19 | 33.28 | 33.37 | 33.46 | 34 |
| 35 | 33.62 | 33.71 | 33.80 | 33.89 | 33.98 | 34.07 | 34.17 | 34.27 | 34.36 | 34.45 | 35 |
| 36 | 34.58 | 34.67 | 34.77 | 34.86 | 34.95 | 35.05 | 35.15 | 35.25 | 35.34 | 35.43 | 36 |
| 37 | 35.54 | 35.63 | 35.73 | 35.83 | 35.92 | 36.02 | 36.12 | 36.22 | 36.32 | 36.42 | 37 |
| 38 | 36.50 | 36.60 | 36.70 | 36.80 | 36.90 | 37.00 | 37.10 | 37.20 | 37.30 | 37.40 | 38 |
| 39 | 37.47 | 37.57 | 37.67 | 37.77 | 37.87 | 37.97 | 38.07 | 38.18 | 38.28 | 38.39 | 39 |
| 40 | 38.42 | 38.52 | 38.64 | 38.74 | 38.84 | 38.95 | 39.05 | 39.16 | 39.26 | 39.37 | 40 |
| 41 | 39.38 | 39.48 | 39.60 | 39.71 | 39.81 | 39.92 | 40.02 | 40.14 | 40.24 | 40.36 | 41 |
| 42 | 40.34 | 40.44 | 40.56 | 40.68 | 40.78 | 40.89 | 41.00 | 41.12 | 41.22 | 41.34 | 42 |
| 43 | 41.30 | 41.41 | 41.53 | 41.64 | 41.75 | 41.86 | 41.97 | 42.10 | 42.20 | 42.32 | 43 |
| 44 | 42.27 | 42.38 | 42.50 | 42.62 | 42.73 | 42.84 | 42.95 | 43.07 | 43.18 | 43.30 | 44 |
| 45 | 43.22 | 43.34 | 43.46 | 43.58 | 43.69 | 43.81 | 43.93 | 44.06 | 44.17 | 44.29 | 45 |
| 46 | 44.18 | 44.30 | 44.42 | 44.54 | 44.66 | 44.78 | 44.90 | 45.03 | 45.15 | 45.27 | 46 |
| 47 | 45.15 | 45.26 | 45.39 | 45.52 | 45.64 | 45.76 | 45.88 | 46.01 | 46.13 | 46.26 | 47 |
| 48 | 46.10 | 46.23 | 46.36 | 46.49 | 46.61 | 46.73 | 46.85 | 46.99 | 47.12 | 47.24 | 48 |
| 49 | 47.06 | 47.19 | 47.32 | 47.44 | 47.57 | 47.70 | 47.83 | 47.97 | 48.10 | 48.23 | 49 |
| 50 | 48.03 | 48.16 | 48.30 | 48.42 | 48.55 | 48.68 | 48.82 | 48.95 | 49.08 | 49.21 | 50 |

REDUCTION OF THE VOLUME OF GASES 29

volumes of gases to a pressure of 760 mm.—*Continued.*

| 760 | 780 | 782 | 784 | 786 | 788 | 740 | 742 | 744 | 746 | 748 | 760 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 51 | 48.99 | 49.12 | 49.26 | 49.39 | 49.52 | 49.65 | 49.79 | 49.98 | 50.06 | 50.19 | 51 |
| 52 | 49.96 | 50.08 | 50.22 | 50.36 | 50.49 | 50.68 | 50.77 | 50.91 | 51.04 | 51.18 | 52 |
| 53 | 50.91 | 51.05 | 51.19 | 51.33 | 51.46 | 51.60 | 51.75 | 51.89 | 52.02 | 52.16 | 53 |
| 54 | 51.87 | 52.01 | 52.16 | 52.30 | 52.44 | 52.58 | 52.72 | 52.87 | 53.01 | 53.15 | 54 |
| 55 | 52.83 | 52.98 | 53.13 | 53.27 | 53.41 | 53.55 | 53.70 | 53.85 | 53.99 | 54.14 | 55 |
| 56 | 53.79 | 53.94 | 54.09 | 54.23 | 54.37 | 54.52 | 54.68 | 54.83 | 54.97 | 55.11 | 56 |
| 57 | 54.75 | 54.90 | 55.05 | 55.20 | 55.35 | 55.50 | 55.65 | 55.80 | 55.95 | 56.10 | 57 |
| 58 | 55.71 | 55.86 | 56.02 | 56.17 | 56.32 | 56.47 | 56.63 | 56.78 | 56.93 | 57.08 | 58 |
| 59 | 56.67 | 56.83 | 56.99 | 57.14 | 57.29 | 57.44 | 57.60 | 57.76 | 57.92 | 58.07 | 59 |
| 60 | 57.63 | 57.79 | 57.95 | 58.10 | 58.26 | 58.42 | 58.58 | 58.74 | 58.90 | 59.05 | 60 |
| 61 | 58.59 | 58.75 | 58.91 | 59.07 | 59.23 | 59.39 | 59.56 | 59.72 | 59.88 | 60.04 | 61 |
| 62 | 59.55 | 59.72 | 59.88 | 60.04 | 60.20 | 60.36 | 60.53 | 60.70 | 60.86 | 61.02 | 62 |
| 63 | 60.51 | 60.68 | 60.85 | 61.01 | 61.17 | 61.34 | 61.51 | 61.68 | 61.84 | 62.00 | 63 |
| 64 | 61.47 | 61.64 | 61.81 | 61.98 | 62.15 | 62.32 | 62.49 | 62.66 | 62.82 | 62.99 | 64 |
| 65 | 62.43 | 62.60 | 62.77 | 62.94 | 63.11 | 63.28 | 63.46 | 63.64 | 63.81 | 63.98 | 65 |
| 66 | 63.39 | 63.57 | 63.74 | 63.91 | 64.08 | 64.26 | 64.44 | 64.62 | 64.79 | 64.96 | 66 |
| 67 | 64.35 | 64.53 | 64.71 | 64.88 | 65.05 | 65.23 | 65.41 | 65.59 | 65.77 | 65.94 | 67 |
| 68 | 65.31 | 65.50 | 65.68 | 65.85 | 66.02 | 66.20 | 66.38 | 66.56 | 66.74 | 66.92 | 68 |
| 69 | 66.27 | 66.45 | 66.64 | 66.82 | 67.00 | 67.18 | 67.37 | 67.55 | 67.73 | 67.91 | 69 |
| 70 | 67.24 | 67.42 | 67.61 | 67.79 | 67.97 | 68.16 | 68.34 | 68.53 | 68.71 | 68.89 | 70 |
| 71 | 68.20 | 68.39 | 68.58 | 68.76 | 68.94 | 69.13 | 69.32 | 69.51 | 69.69 | 69.88 | 71 |
| 72 | 69.16 | 69.35 | 69.54 | 69.73 | 69.92 | 70.11 | 70.30 | 70.49 | 70.68 | 70.86 | 72 |
| 73 | 70.12 | 70.31 | 70.51 | 70.69 | 70.88 | 71.08 | 71.27 | 71.47 | 71.66 | 71.85 | 73 |
| 74 | 71.08 | 71.28 | 71.48 | 71.66 | 71.85 | 72.05 | 72.25 | 72.45 | 72.64 | 72.83 | 74 |
| 75 | 72.04 | 72.24 | 72.44 | 72.63 | 72.82 | 73.02 | 73.22 | 73.42 | 73.62 | 73.82 | 75 |
| 76 | 73.00 | 73.20 | 73.40 | 73.60 | 73.80 | 74.00 | 74.20 | 74.40 | 74.60 | 74.80 | 76 |
| 77 | 73.96 | 74.17 | 74.37 | 74.57 | 74.77 | 74.97 | 75.18 | 75.39 | 75.59 | 75.79 | 77 |
| 78 | 74.93 | 75.12 | 75.33 | 75.53 | 75.74 | 75.95 | 76.16 | 76.37 | 76.57 | 76.77 | 78 |
| 79 | 75.88 | 76.09 | 76.30 | 76.50 | 76.71 | 76.92 | 77.13 | 77.34 | 77.55 | 77.75 | 79 |
| 80 | 76.84 | 77.05 | 77.27 | 77.47 | 77.68 | 77.90 | 78.10 | 78.32 | 78.53 | 78.74 | 80 |
| 81 | 77.80 | 78.02 | 78.23 | 78.44 | 78.65 | 78.87 | 79.08 | 79.30 | 79.51 | 79.72 | 81 |
| 82 | 78.76 | 78.98 | 79.20 | 79.41 | 79.62 | 79.84 | 80.06 | 80.28 | 80.50 | 80.71 | 82 |
| 83 | 79.72 | 79.94 | 80.16 | 80.38 | 80.60 | 80.82 | 81.04 | 81.26 | 81.48 | 81.69 | 83 |
| 84 | 80.68 | 80.90 | 81.12 | 81.34 | 81.56 | 81.79 | 82.01 | 82.24 | 82.46 | 82.68 | 84 |
| 85 | 81.64 | 81.87 | 82.10 | 82.31 | 82.53 | 82.76 | 82.99 | 83.22 | 83.44 | 83.66 | 85 |
| 86 | 82.60 | 82.83 | 83.06 | 83.28 | 83.50 | 83.73 | 83.97 | 84.20 | 84.42 | 84.64 | 86 |
| 87 | 83.56 | 83.79 | 84.02 | 84.25 | 84.48 | 84.71 | 84.94 | 85.17 | 85.40 | 85.62 | 87 |
| 88 | 84.52 | 84.76 | 85.00 | 85.22 | 85.45 | 85.68 | 85.92 | 86.15 | 86.38 | 86.61 | 88 |
| 89 | 85.48 | 85.72 | 85.95 | 86.19 | 86.42 | 86.66 | 86.89 | 87.13 | 87.36 | 87.59 | 89 |
| 90 | 86.45 | 86.68 | 86.93 | 87.16 | 87.39 | 87.63 | 87.87 | 88.11 | 88.34 | 88.58 | 90 |
| 91 | 87.41 | 87.65 | 87.89 | 88.12 | 88.36 | 88.61 | 88.85 | 89.09 | 89.33 | 89.56 | 91 |
| 92 | 88.37 | 88.61 | 88.86 | 89.09 | 89.33 | 89.58 | 89.82 | 90.07 | 90.31 | 90.55 | 92 |
| 93 | 89.33 | 89.57 | 89.82 | 90.06 | 90.30 | 90.55 | 90.80 | 91.05 | 91.29 | 91.53 | 93 |
| 94 | 90.29 | 90.54 | 90.79 | 91.03 | 91.27 | 91.53 | 91.78 | 92.03 | 92.27 | 92.51 | 94 |
| 95 | 91.25 | 91.50 | 91.75 | 92.00 | 92.25 | 92.50 | 92.75 | 93.00 | 93.25 | 93.50 | 95 |
| 96 | 92.21 | 92.46 | 92.72 | 92.97 | 93.22 | 93.47 | 93.73 | 93.98 | 94.23 | 94.48 | 96 |
| 97 | 93.17 | 93.43 | 93.68 | 93.93 | 94.19 | 94.45 | 94.71 | 94.96 | 95.22 | 95.47 | 97 |
| 98 | 94.13 | 94.39 | 94.65 | 94.90 | 95.16 | 95.42 | 95.68 | 95.94 | 96.20 | 96.45 | 98 |
| 99 | 95.09 | 95.35 | 95.61 | 95.87 | 96.13 | 96.39 | 96.66 | 96.92 | 97.18 | 97.43 | 99 |
| 100 | 96.05 | 96.32 | 96.58 | 96.84 | 97.11 | 97.37 | 97.63 | 97.89 | 98.16 | 98.42 | 100 |

30 THE TECHNICAL CHEMISTS' HANDBOOK

TABLE 1:--Continued. II. Table for reducing the

| 760 | 750 | 752 | 754 | 756 | 758 | 762 | 764 | 766 | 768 | 770 | 760 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1 | 0.987 | 0.989 | 0.992 | 0.995 | 0.997 | 1.008 | 1.005 | 1.008 | 1.011 | 1.018 | 1 |
| 2 | 1.974 | 1.979 | 1.984 | 1.989 | 1.995 | 2.005 | 2.011 | 2.016 | 2.021 | 2.026 | 2 |
| 3 | 2.960 | 2.968 | 2.976 | 2.984 | 2.992 | 3.007 | 3.016 | 3.024 | 3.032 | 3.039 | 3 |
| 4 | 3.947 | 3.958 | 3.968 | 3.979 | 3.990 | 4.010 | 4.021 | 4.032 | 4.042 | 4.052 | 4 |
| 5 | 4.934 | 4.947 | 4.960 | 4.974 | 4.987 | 5.013 | 5.026 | 5.040 | 5.053 | 5.066 | 5 |
| 6 | 5.921 | 5.937 | 5.952 | 5.968 | 5.984 | 6.016 | 6.032 | 6.047 | 6.063 | 6.079 | 6 |
| 7 | 6.908 | 6.926 | 6.944 | 6.963 | 6.982 | 7.018 | 7.037 | 7.055 | 7.074 | 7.092 | 7 |
| 8 | 7.894 | 7.916 | 7.936 | 7.958 | 7.979 | 8.021 | 8.042 | 8.063 | 8.084 | 8.106 | 8 |
| 9 | 8.881 | 8.905 | 8.929 | 8.952 | 8.977 | 9.023 | 9.048 | 9.071 | 9.095 | 9.119 | 9 |
| 10 | 9.867 | 9.89 | 9.92 | 9.95 | 9.97 | 10.03 | 10.05 | 10.08 | 10.11 | 10.13 | 10 |
| 11 | 10.85 | 10.88 | 10.91 | 10.94 | 10.97 | 11.03 | 11.06 | 11.09 | 11.12 | 11.14 | 11 |
| 12 | 11.84 | 11.87 | 11.90 | 11.94 | 11.97 | 12.04 | 12.07 | 12.10 | 12.13 | 12.16 | 12 |
| 13 | 12.83 | 12.86 | 12.89 | 12.93 | 12.96 | 13.04 | 13.07 | 13.10 | 13.14 | 13.17 | 13 |
| 14 | 13.82 | 13.85 | 13.88 | 13.92 | 13.96 | 14.04 | 14.07 | 14.11 | 14.15 | 14.17 | 14 |
| 15 | 14.81 | 14.84 | 14.87 | 14.92 | 14.96 | 15.04 | 15.08 | 15.12 | 15.16 | 15.19 | 15 |
| 16 | 15.79 | 15.83 | 15.87 | 15.91 | 15.95 | 16.05 | 16.09 | 16.18 | 16.17 | 16.21 | 16 |
| 17 | 16.78 | 16.82 | 16.86 | 16.91 | 16.95 | 17.05 | 17.09 | 17.14 | 17.18 | 17.22 | 17 |
| 18 | 17.77 | 17.81 | 17.85 | 17.90 | 17.95 | 18.05 | 18.10 | 18.15 | 18.19 | 18.23 | 18 |
| 19 | 18.75 | 18.80 | 18.85 | 18.90 | 18.95 | 19.05 | 19.10 | 19.15 | 19.20 | 19.25 | 19 |
| 20 | 19.74 | 19.79 | 19.84 | 19.89 | 19.95 | 20.05 | 20.11 | 20.16 | 20.21 | 20.26 | 20 |
| 21 | 20.72 | 20.77 | 20.83 | 20.89 | 20.94 | 21.05 | 21.11 | 21.17 | 21.22 | 21.27 | 21 |
| 22 | 21.71 | 21.76 | 21.82 | 21.88 | 21.94 | 22.06 | 22.12 | 22.18 | 22.23 | 22.28 | 22 |
| 23 | 22.70 | 22.75 | 22.81 | 22.88 | 22.94 | 23.06 | 23.12 | 23.18 | 23.24 | 23.30 | 23 |
| 24 | 23.69 | 23.74 | 23.80 | 23.87 | 23.93 | 24.06 | 24.13 | 24.19 | 24.25 | 24.31 | 24 |
| 25 | 24.67 | 24.73 | 24.80 | 24.87 | 24.93 | 25.06 | 25.13 | 25.20 | 25.26 | 25.32 | 25 |
| 26 | 25.66 | 25.72 | 25.79 | 25.86 | 25.93 | 26.06 | 26.14 | 26.21 | 26.27 | 26.34 | 26 |
| 27 | 26.65 | 26.71 | 26.78 | 26.86 | 26.93 | 27.07 | 27.15 | 27.22 | 27.28 | 27.35 | 27 |
| 28 | 27.63 | 27.70 | 27.77 | 27.85 | 27.92 | 28.07 | 28.15 | 28.23 | 28.29 | 28.36 | 28 |
| 29 | 28.62 | 28.69 | 28.76 | 28.84 | 28.92 | 29.07 | 29.16 | 29.24 | 29.30 | 29.37 | 29 |
| 30 | 29.60 | 29.68 | 29.76 | 29.84 | 29.92 | 30.07 | 30.16 | 30.24 | 30.32 | 30.39 | 30 |
| 31 | 30.59 | 30.67 | 30.75 | 30.84 | 30.92 | 31.08 | 31.17 | 31.25 | 31.33 | 31.41 | 31 |
| 32 | 31.58 | 31.66 | 31.74 | 31.83 | 31.92 | 32.08 | 32.17 | 32.26 | 32.34 | 32.42 | 32 |
| 33 | 32.56 | 32.65 | 32.73 | 32.82 | 32.91 | 33.08 | 33.18 | 33.27 | 33.35 | 33.43 | 33 |
| 34 | 33.55 | 33.64 | 33.73 | 33.82 | 33.91 | 34.09 | 34.18 | 34.28 | 34.36 | 34.45 | 34 |
| 35 | 34.54 | 34.63 | 34.72 | 34.82 | 34.91 | 35.09 | 35.19 | 35.28 | 35.37 | 35.46 | 35 |
| 36 | 35.52 | 35.62 | 35.71 | 35.81 | 35.91 | 36.09 | 36.19 | 36.29 | 36.38 | 36.47 | 36 |
| 37 | 36.51 | 36.61 | 36.71 | 36.81 | 36.90 | 37.09 | 37.20 | 37.30 | 37.39 | 37.49 | 37 |
| 38 | 37.50 | 37.60 | 37.70 | 37.80 | 37.90 | 38.10 | 38.20 | 38.30 | 38.40 | 38.50 | 38 |
| 39 | 38.49 | 38.59 | 38.69 | 38.79 | 38.90 | 39.10 | 39.21 | 39.31 | 39.41 | 39.51 | 39 |
| 40 | 39.47 | 39.58 | 39.68 | 39.79 | 39.90 | 40.10 | 40.21 | 40.32 | 40.42 | 40.52 | 40 |
| 41 | 40.46 | 40.56 | 40.67 | 40.79 | 40.89 | 41.11 | 41.22 | 41.33 | 41.43 | 41.54 | 41 |
| 42 | 41.44 | 41.55 | 41.66 | 41.78 | 41.89 | 42.11 | 42.22 | 42.34 | 42.44 | 42.55 | 42 |
| 43 | 42.43 | 42.54 | 42.66 | 42.78 | 42.89 | 43.11 | 43.23 | 43.35 | 43.45 | 43.56 | 43 |
| 44 | 43.42 | 43.53 | 43.65 | 43.77 | 43.89 | 44.12 | 44.23 | 44.35 | 44.46 | 44.58 | 44 |
| 45 | 44.40 | 44.52 | 44.64 | 44.76 | 44.88 | 45.12 | 45.24 | 45.36 | 45.47 | 45.59 | 45 |
| 46 | 45.39 | 45.51 | 45.63 | 45.76 | 45.88 | 46.12 | 46.24 | 46.36 | 46.48 | 46.60 | 46 |
| 47 | 46.38 | 46.50 | 46.63 | 46.76 | 46.88 | 47.12 | 47.25 | 47.38 | 47.49 | 47.61 | 47 |
| 48 | 47.36 | 47.49 | 47.62 | 47.75 | 47.87 | 48.18 | 48.25 | 48.39 | 48.51 | 48.63 | 48 |
| 49 | 48.35 | 48.48 | 48.61 | 48.74 | 48.87 | 49.18 | 49.26 | 49.40 | 49.52 | 49.64 | 49 |
| 50 | 49.34 | 49.47 | 49.60 | 49.74 | 49.87 | 50.18 | 50.26 | 50.40 | 50.53 | 50.66 | 50 |

REDUCTION OF THE VOLUME OF GASES 31

volumes of gases to a pressure of 760 mm.—*Continued.*

| 760 | 750 | 752 | 754 | 756 | 758 | 762 | 764 | 766 | 768 | 770 | 760 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 51 | 50.83 | 50.46 | 50.60 | 50.74 | 50.87 | 51.14 | 51.27 | 51.41 | 51.54 | 51.67 | 51 |
| 52 | 51.82 | 51.45 | 51.59 | 51.73 | 51.87 | 52.14 | 52.28 | 52.42 | 52.55 | 52.68 | 52 |
| 53 | 52.80 | 52.44 | 52.58 | 52.73 | 52.87 | 53.14 | 53.28 | 53.42 | 53.56 | 53.70 | 53 |
| 54 | 53.29 | 52.88 | 53.03 | 53.17 | 53.31 | 53.58 | 53.72 | 53.86 | 54.00 | 54.14 | 54 |
| 55 | 54.28 | 53.87 | 54.01 | 54.15 | 54.29 | 54.56 | 54.70 | 54.84 | 54.98 | 55.12 | 55 |
| 56 | 55.26 | 54.85 | 54.99 | 55.13 | 55.27 | 55.54 | 55.68 | 55.82 | 55.96 | 56.10 | 56 |
| 57 | 56.25 | 55.84 | 55.98 | 56.12 | 56.26 | 56.53 | 56.67 | 56.81 | 56.95 | 57.09 | 57 |
| 58 | 57.24 | 56.83 | 56.97 | 57.11 | 57.25 | 57.52 | 57.66 | 57.80 | 57.94 | 58.08 | 58 |
| 59 | 58.22 | 57.81 | 57.95 | 58.09 | 58.23 | 58.50 | 58.64 | 58.78 | 58.92 | 59.06 | 59 |
| 60 | 59.21 | 58.80 | 58.94 | 59.08 | 59.22 | 59.49 | 59.63 | 59.77 | 59.91 | 60.05 | 60 |
| 61 | 60.20 | 59.79 | 59.93 | 60.07 | 60.21 | 60.48 | 60.62 | 60.76 | 60.90 | 61.04 | 61 |
| 62 | 61.19 | 60.78 | 60.92 | 61.06 | 61.20 | 61.47 | 61.61 | 61.75 | 61.89 | 62.03 | 62 |
| 63 | 62.17 | 61.76 | 61.90 | 62.04 | 62.18 | 62.45 | 62.59 | 62.73 | 62.87 | 63.01 | 63 |
| 64 | 63.16 | 62.75 | 62.89 | 63.03 | 63.17 | 63.44 | 63.58 | 63.72 | 63.86 | 64.00 | 64 |
| 65 | 64.15 | 63.74 | 63.88 | 64.02 | 64.16 | 64.43 | 64.57 | 64.71 | 64.85 | 64.99 | 65 |
| 66 | 65.13 | 64.72 | 64.86 | 65.00 | 65.14 | 65.41 | 65.55 | 65.69 | 65.83 | 65.97 | 66 |
| 67 | 66.12 | 65.71 | 65.85 | 65.99 | 66.13 | 66.40 | 66.54 | 66.68 | 66.82 | 66.96 | 67 |
| 68 | 67.10 | 66.69 | 66.83 | 66.97 | 67.11 | 67.38 | 67.52 | 67.66 | 67.80 | 67.94 | 68 |
| 69 | 68.09 | 67.68 | 67.82 | 67.96 | 68.10 | 68.37 | 68.51 | 68.65 | 68.79 | 68.93 | 69 |
| 70 | 69.08 | 68.67 | 68.81 | 68.95 | 69.09 | 69.36 | 69.50 | 69.64 | 69.78 | 69.92 | 70 |
| 71 | 70.07 | 69.66 | 69.80 | 69.94 | 70.08 | 70.35 | 70.49 | 70.63 | 70.77 | 70.91 | 71 |
| 72 | 71.05 | 70.64 | 70.78 | 70.92 | 71.06 | 71.33 | 71.47 | 71.61 | 71.75 | 71.89 | 72 |
| 73 | 72.04 | 71.63 | 71.77 | 71.91 | 72.05 | 72.32 | 72.46 | 72.60 | 72.74 | 72.88 | 73 |
| 74 | 73.03 | 72.62 | 72.76 | 72.90 | 73.04 | 73.31 | 73.45 | 73.59 | 73.73 | 73.87 | 74 |
| 75 | 74.01 | 73.60 | 73.74 | 73.88 | 74.02 | 74.29 | 74.43 | 74.57 | 74.71 | 74.85 | 75 |
| 76 | 75.00 | 74.59 | 74.73 | 74.87 | 75.01 | 75.28 | 75.42 | 75.56 | 75.70 | 75.84 | 76 |
| 77 | 75.99 | 75.58 | 75.72 | 75.86 | 76.00 | 76.27 | 76.41 | 76.55 | 76.69 | 76.83 | 77 |
| 78 | 76.97 | 76.56 | 76.70 | 76.84 | 76.98 | 77.25 | 77.39 | 77.53 | 77.67 | 77.81 | 78 |
| 79 | 77.96 | 77.55 | 77.69 | 77.83 | 77.97 | 78.24 | 78.38 | 78.52 | 78.66 | 78.80 | 79 |
| 80 | 78.94 | 78.53 | 78.67 | 78.81 | 78.95 | 79.22 | 79.36 | 79.50 | 79.64 | 79.78 | 80 |
| 81 | 79.93 | 79.52 | 79.66 | 79.80 | 79.94 | 80.21 | 80.35 | 80.49 | 80.63 | 80.77 | 81 |
| 82 | 80.92 | 80.51 | 80.65 | 80.79 | 80.93 | 81.20 | 81.34 | 81.48 | 81.62 | 81.76 | 82 |
| 83 | 81.91 | 81.50 | 81.64 | 81.78 | 81.92 | 82.19 | 82.33 | 82.47 | 82.61 | 82.75 | 83 |
| 84 | 82.90 | 82.49 | 82.63 | 82.77 | 82.91 | 83.18 | 83.32 | 83.46 | 83.60 | 83.74 | 84 |
| 85 | 83.88 | 83.47 | 83.61 | 83.75 | 83.89 | 84.16 | 84.30 | 84.44 | 84.58 | 84.72 | 85 |
| 86 | 84.87 | 84.46 | 84.60 | 84.74 | 84.88 | 85.15 | 85.29 | 85.43 | 85.57 | 85.71 | 86 |
| 87 | 85.85 | 85.44 | 85.58 | 85.72 | 85.86 | 86.13 | 86.27 | 86.41 | 86.55 | 86.69 | 87 |
| 88 | 86.84 | 86.43 | 86.57 | 86.71 | 86.85 | 87.12 | 87.26 | 87.40 | 87.54 | 87.68 | 88 |
| 89 | 87.82 | 87.41 | 87.55 | 87.69 | 87.83 | 88.10 | 88.24 | 88.38 | 88.52 | 88.66 | 89 |
| 90 | 88.81 | 88.40 | 88.54 | 88.68 | 88.82 | 89.09 | 89.23 | 89.37 | 89.51 | 89.65 | 90 |
| 91 | 89.80 | 89.39 | 89.53 | 89.67 | 89.81 | 90.08 | 90.22 | 90.36 | 90.50 | 90.64 | 91 |
| 92 | 90.79 | 90.38 | 90.52 | 90.66 | 90.80 | 91.07 | 91.21 | 91.35 | 91.49 | 91.63 | 92 |
| 93 | 91.77 | 91.36 | 91.50 | 91.64 | 91.78 | 92.05 | 92.19 | 92.33 | 92.47 | 92.61 | 93 |
| 94 | 92.76 | 92.35 | 92.49 | 92.63 | 92.77 | 93.04 | 93.18 | 93.32 | 93.46 | 93.60 | 94 |
| 95 | 93.74 | 93.33 | 93.47 | 93.61 | 93.75 | 94.02 | 94.16 | 94.30 | 94.44 | 94.58 | 95 |
| 96 | 94.73 | 94.32 | 94.46 | 94.60 | 94.74 | 95.01 | 95.15 | 95.29 | 95.43 | 95.57 | 96 |
| 97 | 95.72 | 95.31 | 95.45 | 95.59 | 95.73 | 96.00 | 96.14 | 96.28 | 96.42 | 96.56 | 97 |
| 98 | 96.70 | 96.29 | 96.43 | 96.57 | 96.71 | 96.98 | 97.12 | 97.26 | 97.40 | 97.54 | 98 |
| 99 | 97.69 | 97.28 | 97.42 | 97.56 | 97.70 | 97.97 | 98.11 | 98.25 | 98.39 | 98.53 | 99 |
| 100 | 98.68 | 98.27 | 98.41 | 98.55 | 98.69 | 98.96 | 99.10 | 99.24 | 99.38 | 99.52 | 100 |

TABLE 13.—FACTORS FOR REDUCING A
TEMPERATURE

0° Centigrade, and 760 millimetres, or 32°

| Centigrade. | | 0.0. | 1.1. | 2.2. | 3.3. | 4.4. | 5.6. | 6.7. | 7.8. | 8.9. |
|-------------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Fahrenheit. | | 32°. | 34°. | 36°. | 38°. | 40°. | 42°. | 44°. | 46°. | 48°. |
| In. | Milli- metres. | | | | | | | | | |
| 27.5 | 698.5 | .9191 | .9154 | .9116 | .9079 | .9043 | .9007 | .8972 | .8936 | .8899 |
| 27.6 | 701.0 | .9224 | .9188 | .9149 | .9112 | .9076 | .9039 | .9005 | .8969 | .8932 |
| 27.7 | 703.6 | .9258 | .9221 | .9183 | .9145 | .9109 | .9072 | .9037 | .9001 | .8964 |
| 27.8 | 706.1 | .9291 | .9254 | .9215 | .9179 | .9142 | .9105 | .9070 | .9034 | .8996 |
| 27.9 | 708.6 | .9325 | .9288 | .9249 | .9212 | .9174 | .9138 | .9102 | .9067 | .9029 |
| | | | | | | | | | | |
| 28.0 | 711.2 | .9358 | .9321 | .9282 | .9244 | .9208 | .9170 | .9135 | .9099 | .9061 |
| 28.1 | 713.7 | .9391 | .9354 | .9315 | .9278 | .9241 | .9203 | .9167 | .9131 | .9093 |
| 28.2 | 716.3 | .9425 | .9387 | .9348 | .9310 | .9273 | .9236 | .9200 | .9164 | .9125 |
| 28.3 | 718.8 | .9458 | .9421 | .9382 | .9344 | .9306 | .9269 | .9233 | .9197 | .9158 |
| 28.4 | 721.3 | .9491 | .9454 | .9415 | .9377 | .9339 | .9301 | .9265 | .9229 | .9190 |
| | | | | | | | | | | |
| 28.5 | 723.9 | .9525 | .9487 | .9448 | .9410 | .9372 | .9334 | .9298 | .9262 | .9223 |
| 28.6 | 726.4 | .9558 | .9520 | .9481 | .9443 | .9405 | .9367 | .9331 | .9294 | .9255 |
| 28.7 | 728.9 | .9592 | .9554 | .9514 | .9476 | .9438 | .9400 | .9364 | .9327 | .9287 |
| 28.8 | 731.5 | .9625 | .9587 | .9547 | .9509 | .9471 | .9432 | .9396 | .9359 | .9320 |
| 28.9 | 734.0 | .9659 | .9620 | .9580 | .9542 | .9504 | .9465 | .9429 | .9392 | .9352 |
| | | | | | | | | | | |
| 29.0 | 736.6 | .9692 | .9654 | .9613 | .9575 | .9536 | .9498 | .9462 | .9424 | .9385 |
| 29.1 | 739.1 | .9725 | .9687 | .9647 | .9608 | .9569 | .9531 | .9494 | .9457 | .9417 |
| 29.2 | 741.6 | .9759 | .9720 | .9680 | .9640 | .9602 | .9563 | .9527 | .9489 | .9449 |
| 29.3 | 744.2 | .9792 | .9753 | .9713 | .9674 | .9635 | .9596 | .9559 | .9522 | .9481 |
| 29.4 | 746.7 | .9826 | .9787 | .9746 | .9707 | .9668 | .9629 | .9592 | .9554 | .9514 |
| | | | | | | | | | | |
| 29.5 | 749.3 | .9859 | .9820 | .9779 | .9740 | .9701 | .9662 | .9624 | .9587 | .9546 |
| 29.6 | 751.8 | .9893 | .9853 | .9812 | .9773 | .9733 | .9694 | .9657 | .9619 | .9578 |
| 29.7 | 754.3 | .9926 | .9887 | .9845 | .9806 | .9766 | .9727 | .9690 | .9652 | .9611 |
| 29.8 | 756.9 | .9959 | .9920 | .9879 | .9839 | .9800 | .9760 | .9722 | .9684 | .9643 |
| 29.9 | 759.4 | .9993 | .9954 | .9912 | .9872 | .9832 | .9793 | .9755 | .9717 | .9676 |
| | | | | | | | | | | |
| 30.0 | 762.0 | 1.0026 | .9987 | .9945 | .9905 | .9865 | .9826 | .9788 | .9749 | .9708 |
| 30.1 | 764.5 | 1.0060 | 1.0020 | .9978 | .9938 | .9898 | .9858 | .9820 | .9782 | .9740 |
| 30.2 | 767.0 | 1.0093 | 1.0053 | 1.0011 | .9971 | .9931 | .9891 | .9853 | .9814 | .9773 |
| 30.3 | 769.6 | 1.0126 | 1.0086 | 1.0044 | 1.0004 | .9964 | .9924 | .9885 | .9846 | .9805 |
| 30.4 | 772.1 | 1.0160 | 1.0120 | 1.0078 | 1.0037 | .9997 | .9957 | .9918 | .9879 | .9837 |
| | | | | | | | | | | |
| 30.5 | 774.7 | 1.0194 | 1.0153 | 1.0111 | 1.0070 | 1.0030 | .9989 | .9950 | .9911 | .9870 |
| 30.6 | 777.2 | 1.0227 | 1.0186 | 1.0144 | 1.0103 | 1.0063 | 1.0022 | .9983 | .9944 | .9902 |
| 30.7 | 779.7 | 1.0260 | 1.0220 | 1.0177 | 1.0136 | 1.0096 | 1.0055 | 1.0016 | .9976 | .9935 |
| 30.8 | 782.3 | 1.0294 | 1.0253 | 1.0210 | 1.0169 | 1.0128 | 1.0087 | 1.0048 | 1.0009 | .9967 |
| 30.9 | 784.8 | 1.0327 | 1.0286 | 1.0243 | 1.0202 | 1.0161 | 1.0120 | 1.0081 | 1.0041 | 1.0000 |
| 31.0 | 787.4 | 1.0360 | 1.0319 | 1.0276 | 1.0235 | 1.0194 | 1.0153 | 1.0114 | 1.0074 | 1.0032 |

NORMAL TEMPERATURE AND PRESSURE 33

GIVEN VOLUME OF GAS TO NORMAL AND PRESSURE.

Fahrenheit, and 29.92 inches barometric pressure.

| Centigrade. | | 10.0. | 11.1. | 12.2. | 13.3. | 14.4. | 15.6. | 16.7. | 17.8. |
|-------------|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Fahrenheit. | | 50°. | 52°. | 54°. | 56°. | 58°. | 60°. | 62°. | 64°. |
| In. | Milli- metres. | | | | | | | | |
| 27.5 | 698.5 | .8867 | .8882 | .8797 | .8763 | .8728 | .8695 | .8661 | .8628 |
| 27.6 | 701.0 | .8900 | .8864 | .8829 | .8795 | .8760 | .8726 | .8693 | .8660 |
| 27.7 | 703.6 | .8932 | .8897 | .8861 | .8827 | .8792 | .8758 | .8724 | .8691 |
| 27.8 | 706.1 | .8964 | .8928 | .8893 | .8859 | .8823 | .8790 | .8756 | .8722 |
| 27.9 | 708.6 | .8996 | .8960 | .8925 | .8890 | .8855 | .8821 | .8787 | .8754 |
| | | | | | | | | | |
| 28.0 | 711.2 | .9029 | .8992 | .8957 | .8922 | .8887 | .8853 | .8819 | .8785 |
| 28.1 | 713.7 | .9060 | .9025 | .8989 | .8954 | .8919 | .8884 | .8850 | .8816 |
| 28.2 | 716.3 | .9093 | .9057 | .9021 | .8986 | .8951 | .8916 | .8882 | .8848 |
| 28.3 | 718.8 | .9125 | .9089 | .9053 | .9018 | .8983 | .8948 | .8913 | .8879 |
| 28.4 | 721.3 | .9157 | .9121 | .9085 | .9050 | .9014 | .8979 | .8945 | .8911 |
| | | | | | | | | | |
| 28.5 | 723.9 | .9189 | .9153 | .9117 | .9082 | .9046 | .9011 | .8976 | .8942 |
| 28.6 | 726.4 | .9222 | .9185 | .9149 | .9114 | .9077 | .9043 | .9008 | .8973 |
| 28.7 | 728.9 | .9254 | .9218 | .9181 | .9145 | .9109 | .9074 | .9039 | .9005 |
| 28.8 | 731.5 | .9286 | .9250 | .9213 | .9177 | .9141 | .9106 | .9071 | .9036 |
| 28.9 | 734.0 | .9318 | .9282 | .9245 | .9209 | .9173 | .9138 | .9102 | .9067 |
| | | | | | | | | | |
| 29.0 | 736.6 | .9351 | .9314 | .9277 | .9241 | .9205 | .9169 | .9134 | .9099 |
| 29.1 | 739.1 | .9383 | .9346 | .9309 | .9273 | .9236 | .9201 | .9165 | .9130 |
| 29.2 | 741.6 | .9415 | .9378 | .9341 | .9305 | .9268 | .9233 | .9197 | .9162 |
| 29.3 | 744.2 | .9448 | .9411 | .9373 | .9336 | .9300 | .9264 | .9228 | .9193 |
| 29.4 | 746.7 | .9480 | .9443 | .9405 | .9368 | .9332 | .9296 | .9260 | .9224 |
| | | | | | | | | | |
| 29.5 | 749.3 | .9512 | .9475 | .9437 | .9400 | .9363 | .9326 | .9291 | .9256 |
| 29.6 | 751.8 | .9544 | .9506 | .9469 | .9432 | .9395 | .9359 | .9323 | .9287 |
| 29.7 | 754.3 | .9577 | .9539 | .9501 | .9464 | .9427 | .9390 | .9354 | .9318 |
| 29.8 | 756.9 | .9609 | .9571 | .9533 | .9496 | .9459 | .9422 | .9386 | .9350 |
| 29.9 | 759.4 | .9641 | .9603 | .9565 | .9528 | .9490 | .9454 | .9417 | .9381 |
| | | | | | | | | | |
| 30.0 | 762.0 | .9673 | .9635 | .9597 | .9560 | .9522 | .9486 | .9449 | .9413 |
| 30.1 | 764.5 | .9706 | .9667 | .9629 | .9591 | .9554 | .9517 | .9480 | .9444 |
| 30.2 | 767.0 | .9738 | .9700 | .9661 | .9623 | .9586 | .9549 | .9512 | .9475 |
| 30.3 | 769.6 | .9770 | .9731 | .9693 | .9655 | .9617 | .9580 | .9543 | .9507 |
| 30.4 | 772.1 | .9802 | .9764 | .9725 | .9687 | .9649 | .9612 | .9575 | .9538 |
| | | | | | | | | | |
| 30.5 | 774.7 | .9835 | .9796 | .9757 | .9719 | .9681 | .9643 | .9606 | .9569 |
| 30.6 | 777.2 | .9867 | .9828 | .9789 | .9751 | .9712 | .9675 | .9638 | .9601 |
| 30.7 | 779.7 | .9899 | .9860 | .9821 | .9782 | .9744 | .9707 | .9669 | .9632 |
| 30.8 | 782.3 | .9931 | .9892 | .9853 | .9815 | .9777 | .9738 | .9701 | .9664 |
| 30.9 | 784.8 | .9963 | .9924 | .9885 | .9846 | .9807 | .9770 | .9732 | .9695 |
| 31.0 | 787.4 | .9996 | .9956 | .9917 | .9878 | .9840 | .9801 | .9764 | .9726 |

TABLE 13—*Continued.*

| Centigrade. | | 18.9. | 20. | 21.1. | 22.2. | 23.3. | 24.4. | 25.6. | 26.7. |
|-------------|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Fahrenheit. | | 66° | 68°. | 70°. | 72°. | 74°. | 76°. | 78°. | 80°. |
| In. | Milli- metres. | | | | | | | | |
| 27.5 | 698.5 | '8595 | '8563 | '8530 | '8498 | '8466 | '8435 | '8403 | '8372 |
| 27.6 | 701.0 | '8626 | '8594 | '8561 | '8529 | '8497 | '8465 | '8434 | '8403 |
| 27.7 | 703.6 | '8658 | '8625 | '8592 | '8560 | '8528 | '8496 | '8464 | '8433 |
| 27.8 | 706.1 | '8689 | '8656 | '8623 | '8591 | '8559 | '8527 | '8495 | '8463 |
| 27.9 | 708.6 | '8720 | '8687 | '8654 | '8622 | '8589 | '8557 | '8525 | '8494 |
| | | | | | | | | | |
| 28.0 | 711.2 | '8751 | '8718 | '8685 | '8653 | '8620 | '8588 | '8556 | '8524 |
| 28.1 | 713.7 | '8783 | '8750 | '8716 | '8684 | '8651 | '8619 | '8587 | '8555 |
| 28.2 | 716.3 | '8814 | '8781 | '8747 | '8714 | '8682 | '8649 | '8617 | '8585 |
| 28.3 | 718.8 | '8845 | '8812 | '8778 | '8745 | '8713 | '8680 | '8648 | '8616 |
| 28.4 | 721.3 | '8876 | '8843 | '8809 | '8776 | '8743 | '8711 | '8678 | '8646 |
| | | | | | | | | | |
| 28.5 | 723.9 | '8908 | '8874 | '8840 | '8807 | '8774 | '8741 | '8709 | '8677 |
| 28.6 | 726.4 | '8939 | '8905 | '8872 | '8838 | '8805 | '8772 | '8739 | '8707 |
| 28.7 | 728.9 | '8970 | '8936 | '8903 | '8869 | '8836 | '8803 | '8770 | '8738 |
| 28.8 | 731.5 | '9002 | '8968 | '8934 | '8900 | '8866 | '8833 | '8800 | '8768 |
| 28.9 | 734.0 | '9033 | '8999 | '8965 | '8931 | '8897 | '8864 | '8831 | '8798 |
| | | | | | | | | | |
| 29.0 | 736.6 | '9064 | '9030 | '8996 | '8962 | '8928 | '8895 | '8862 | '8829 |
| 29.1 | 739.1 | '9095 | '9061 | '9027 | '8993 | '8959 | '8925 | '8892 | '8859 |
| 29.2 | 741.6 | '9127 | '9092 | '9058 | '9023 | '8990 | '8956 | '8923 | '8890 |
| 29.3 | 744.2 | '9158 | '9123 | '9089 | '9054 | '9020 | '8987 | '8953 | '8920 |
| 29.4 | 746.7 | '9189 | '9154 | '9120 | '9085 | '9051 | '9017 | '8984 | '8951 |
| | | | | | | | | | |
| 29.5 | 749.3 | '9220 | '9186 | '9151 | '9116 | '9082 | '9048 | '9014 | '8981 |
| 29.6 | 751.8 | '9252 | '9217 | '9182 | '9147 | '9113 | '9079 | '9045 | '9012 |
| 29.7 | 754.3 | '9283 | '9248 | '9213 | '9178 | '9144 | '9109 | '9076 | '9042 |
| 29.8 | 756.9 | '9314 | '9279 | '9244 | '9209 | '9174 | '9140 | '9106 | '9072 |
| 29.9 | 759.4 | '9345 | '9310 | '9275 | '9240 | '9205 | '9171 | '9137 | '9103 |
| | | | | | | | | | |
| 30.0 | 762.0 | '9377 | '9341 | '9306 | '9271 | '9236 | '9201 | '9167 | '9133 |
| 30.1 | 764.5 | '9408 | '9372 | '9337 | '9302 | '9267 | '9232 | '9198 | '9164 |
| 30.2 | 767.0 | '9439 | '9403 | '9368 | '9333 | '9297 | '9263 | '9228 | '9194 |
| 30.3 | 769.6 | '9470 | '9435 | '9399 | '9363 | '9328 | '9293 | '9259 | '9225 |
| 30.4 | 772.1 | '9502 | '9466 | '9430 | '9394 | '9359 | '9324 | '9289 | '9255 |
| | | | | | | | | | |
| 30.5 | 774.7 | '9533 | '9497 | '9461 | '9425 | '9389 | '9355 | '9320 | '9286 |
| 30.6 | 777.2 | '9564 | '9528 | '9492 | '9456 | '9421 | '9385 | '9351 | '9316 |
| 30.7 | 779.7 | '9595 | '9559 | '9523 | '9487 | '9451 | '9416 | '9381 | '9346 |
| 30.8 | 782.3 | '9627 | '9590 | '9554 | '9518 | '9482 | '9447 | '9412 | '9377 |
| 30.9 | 784.8 | '9658 | '9621 | '9585 | '9549 | '9513 | '9477 | '9442 | '9407 |
| 31.0 | 787.4 | '9689 | '9653 | '9616 | '9580 | '9544 | '9508 | '9473 | '9438 |

TABLE 14.—VOLUMES OF WATER AT DIFFERENT TEMPERATURES. (Rossetti.)

| Temp. °C. | | Temp. °C. | | Temp. °C. | |
|--------------|----------|--------------|----------|--------------|----------|
| 0 | 1 | 14 | 1·000556 | 40 | 1·007531 |
| 1 | 0·999917 | 15 | 1·000695 | 45 | 1·009541 |
| 2 | 0·999908 | 16 | 1·000846 | 50 | 1·011766 |
| 3 | 0·999885 | 17 | 1·001010 | 55 | 1·014100 |
| 4 | 0·999877 | 18 | 1·001184 | 60 | 1·016590 |
| 5 | 0·999883 | 19 | 1·001376 | 65 | 1·019302 |
| 6 | 0·999903 | 20 | 1·001567 | 70 | 1·022246 |
| 7 | 0·999938 | 21 | 1·001776 | 75 | 1·025410 |
| 8 | 0·999986 | 22 | 1·001995 | 80 | 1·028581 |
| 9 | 1·000048 | 23 | 1·002225 | 85 | 1·031894 |
| 10 | 1·000124 | 24 | 1·002465 | 90 | 1·035397 |
| 11 | 1·000213 | 25 | 1·002717 | 95 | 1·039094 |
| 12 | 1·000314 | 30 | 1·004061 | 100 | 1·042986 |
| 13 | 1·000429 | 35 | 1·005697 | | |

TABLE 15.—REDUCTION OF WATER PRESSURE TO MERCURIAL PRESSURE.

| aq. | Hg. | aq. | Hg. | aq. | Hg. | aq. | Hg. | aq. | Hg. |
|-----|------|-----|------|-----|------|-----|------|------|-------|
| 1 | 0·07 | 23 | 1·70 | 45 | 3·32 | 67 | 4·94 | 89 | 6·57 |
| 2 | 0·15 | 24 | 1·77 | 46 | 3·39 | 68 | 5·02 | 90 | 6·64 |
| 3 | 0·22 | 25 | 1·84 | 47 | 3·47 | 69 | 5·09 | 91 | 6·72 |
| 4 | 0·30 | 26 | 1·92 | 48 | 3·54 | 70 | 5·17 | 92 | 6·79 |
| 5 | 0·37 | 27 | 1·98 | 49 | 3·62 | 71 | 5·24 | 93 | 6·86 |
| 6 | 0·44 | 28 | 2·07 | 50 | 3·69 | 72 | 5·31 | 94 | 6·94 |
| 7 | 0·52 | 29 | 2·11 | 51 | 3·76 | 73 | 5·39 | 95 | 7·01 |
| 8 | 0·59 | 30 | 2·21 | 52 | 3·84 | 74 | 5·46 | 96 | 7·08 |
| 9 | 0·66 | 31 | 2·29 | 53 | 3·91 | 75 | 5·54 | 97 | 7·16 |
| 10 | 0·74 | 32 | 2·36 | 54 | 3·99 | 76 | 5·61 | 98 | 7·23 |
| 11 | 0·81 | 33 | 2·44 | 55 | 4·06 | 77 | 5·68 | 99 | 7·31 |
| 12 | 0·89 | 34 | 2·51 | 56 | 4·13 | 78 | 5·76 | 100 | 7·38 |
| 13 | 0·96 | 35 | 2·58 | 57 | 4·21 | 79 | 5·83 | 200 | 14·76 |
| 14 | 1·03 | 36 | 2·66 | 58 | 4·28 | 80 | 5·90 | 300 | 22·14 |
| 15 | 1·12 | 37 | 2·73 | 59 | 4·35 | 81 | 5·98 | 400 | 29·52 |
| 16 | 1·18 | 38 | 2·80 | 60 | 4·43 | 82 | 6·05 | 500 | 36·90 |
| 17 | 1·26 | 39 | 2·88 | 61 | 4·50 | 83 | 6·13 | 600 | 44·28 |
| 18 | 1·33 | 40 | 2·95 | 62 | 4·58 | 84 | 6·20 | 700 | 51·66 |
| 19 | 1·40 | 41 | 3·03 | 63 | 4·65 | 85 | 6·27 | 800 | 59·04 |
| 20 | 1·48 | 42 | 3·10 | 64 | 4·72 | 86 | 6·35 | 900 | 66·42 |
| 21 | 1·55 | 43 | 3·17 | 65 | 4·80 | 87 | 6·42 | 1000 | 73·80 |
| 22 | 1·62 | 44 | 3·25 | 66 | 4·87 | 88 | 6·49 | | |

TABLE 16.—TENSION OF AQUEOUS VAPOUR.

Between -20° and $+118^{\circ}$ C. in Millimetres Mercury.
(Magnus.)

| T. | mm. | T. | mm. | T. | mm. |
|---------------|-------|--------------|--------|---------------|--------|
| -20° | 0.916 | $+5^{\circ}$ | 6.471 | $+30^{\circ}$ | 31.602 |
| 19 | 0.999 | 6 | 6.939 | 31 | 33.5 |
| 18 | 1.089 | 7 | 7.436 | 32 | 35.4 |
| 17 | 1.186 | 8 | 7.964 | 33 | 37.5 |
| 16 | 1.290 | 9 | 8.525 | 34 | 39.6 |
| 15 | 1.403 | 10 | 9.126 | 35 | 41.9 |
| 14 | 1.525 | 11 | 9.756 | 36 | 44.3 |
| 13 | 1.655 | 12 | 10.421 | 37 | 46.8 |
| 12 | 1.796 | 13 | 11.130 | 38 | 49.4 |
| 11 | 1.947 | 14 | 11.882 | 39 | 52.1 |
| 10 | 2.109 | 15 | 12.677 | 40 | 55.0 |
| 9 | 2.284 | 16 | 13.519 | 41 | 58.0 |
| 8 | 2.471 | 17 | 14.409 | 42 | 61.1 |
| 7 | 2.671 | 18 | 15.351 | 43 | 64.4 |
| 6 | 2.886 | 19 | 16.345 | 44 | 67.8 |
| 5 | 3.110 | 20 | 17.396 | 45 | 71.4 |
| 4 | 3.361 | 21 | 18.505 | 46 | 75.2 |
| 3 | 3.624 | 22 | 19.675 | 47 | 79.1 |
| 2 | 3.900 | 23 | 20.909 | 48 | 83.2 |
| 1 | 4.205 | 24 | 22.211 | 49 | 87.5 |
| 0 | 4.525 | 25 | 23.582 | 50 | 92.0 |
| $+1$ | 4.867 | 26 | 25.026 | 51 | 96.6 |
| 2 | 5.231 | 27 | 26.547 | 52 | 101.5 |
| 3 | 5.619 | 28 | 28.148 | 53 | 106.6 |
| 4 | 6.032 | 29 | 29.832 | 54 | 111.9 |

TABLE 16—*Continued.*

| T. | mm. | T. | mm. | T. | mm. |
|------|-------|------|-------|------|--------|
| +55° | 117·4 | +77° | 312·9 | +99° | 733·1 |
| 56 | 123·1 | 78 | 326·1 | 100 | 760·0 |
| 57 | 129·1 | 79 | 339·8 | 101 | 787·7 |
| 58 | 135·3 | 80 | 353·9 | 102 | 816·3 |
| 59 | 141·8 | 81 | 368·6 | 103 | 845·7 |
| 60 | 148·6 | 82 | 383·7 | 104 | 876·0 |
| 61 | 155·6 | 83 | 399·4 | 105 | 907·1 |
| 62 | 162·9 | 84 | 415·6 | 106 | 939·2 |
| 63 | 170·5 | 85 | 432·3 | 107 | 972·3 |
| 64 | 178·4 | 86 | 449·6 | 108 | 1006·3 |
| 65 | 186·6 | 87 | 467·5 | 109 | 1041·3 |
| 66 | 195·1 | 88 | 486·0 | 110 | 1077·3 |
| 67 | 204·0 | 89 | 505·0 | 111 | 1114·3 |
| 68 | 213·2 | 90 | 524·8 | 112 | 1152·3 |
| 69 | 222·7 | 91 | 545·1 | 113 | 1191·4 |
| 70 | 232·6 | 92 | 566·1 | 114 | 1231·7 |
| 71 | 242·9 | 93 | 587·8 | 115 | 1273·0 |
| 72 | 253·5 | 94 | 610·2 | 116 | 1315·5 |
| 73 | 264·6 | 95 | 633·3 | 117 | 1359·1 |
| 74 | 276·0 | 96 | 657·1 | 118 | 1403·9 |
| 75 | 287·9 | 97 | 681·7 | | |
| 76 | 300·2 | 98 | 707·0 | | |

TABLE 17.—TENSION OF AQUEOUS VAPOUR FOR TEMPERATURES FROM 40° C.

| Temperature Centigrade. | Tension in mm. of Mercury. | Pressure in atmospheres. | Pressure per sq. cm. in kilos. |
|----------------------------|-------------------------------|-----------------------------|-----------------------------------|
| + 40° | 54·906 | 0·072 | 0·07465 |
| 45 | 71·391 | 0·094 | 0·09706 |
| 50 | 91·982 | 0·121 | 0·12505 |
| 55 | 117·473 | 0·154 | 0·15972 |
| 60 | 143·791 | 0·196 | 0·20323 |
| 65 | 186·945 | 0·246 | 0·25417 |
| 70 | 233·093 | 0·306 | 0·31692 |
| 75 | 288·517 | 0·380 | 0·39227 |
| 80 | 354·643 | 0·466 | 0·48217 |
| 85 | 433·041 | 0·570 | 0·58877 |
| 90 | 525·450 | 0·691 | 0·71440 |
| 95 | 633·778 | 0·834 | 0·86168 |
| 100 | 760·00 | 1·000 | 1·03330 |
| 105 | 906·41 | 1·193 | 1·23236 |
| 110 | 1075·37 | 1·415 | 1·46210 |
| 115 | 1269·41 | 1·673 | 1·72592 |
| 120 | 1491·28 | 1·962 | 2·02755 |
| 125 | 1743·88 | 2·294 | 2·37098 |
| 130 | 2030·28 | 2·671 | 2·76037 |
| 135 | 2353·73 | 3·097 | 3·20013 |
| 140 | 2717·63 | 3·575 | 3·69490 |
| 145 | 3125·55 | 4·112 | 4·24950 |
| 150 | 3581·23 | 4·712 | 4·86904 |
| 155 | 4088·56 | 5·380 | 5·55881 |
| 160 | 4651·62 | 6·120 | 6·32434 |
| 165 | 5274·54 | 6·940 | 7·17127 |
| 170 | 5961·66 | 7·814 | 8·10547 |
| 175 | 6717·43 | 8·838 | 9·13302 |
| 180 | 7546·39 | 9·929 | 10·2601 |
| 185 | 8453·23 | 11·122 | 11·4930 |
| 190 | 9442·70 | 12·424 | 12·8383 |
| 195 | 10519·73 | 13·841 | 14·3025 |
| 200 | 11688·96 | 15·380 | 15·8923 |
| 205 | 12955·66 | 17·047 | 17·6145 |
| 210 | 14324·80 | 18·848 | 19·4760 |
| 215 | 15801·33 | 20·791 | 21·4835 |
| 220 | 17390·00 | 22·881 | 23·6439 |
| 225 | 19097·04 | 25·127 | 25·9643 |
| 230 | 20926·40 | 27·534 | 28·4515 |

TABLE 17 — *Continued.* TENSION OF AQUEOUS VAPOUR FOR TEMPERATURES FROM 40° F.

| Temperature Fahrenheit. | Tension in inches of Mercury. | Pressure in atmospheres. | Pressure in l.s. per square inch. |
|----------------------------|----------------------------------|-----------------------------|--------------------------------------|
| 100° | 1·918 | ·064 | ·941 |
| 110 | 2·577 | ·086 | 1·267 |
| 120 | 3·427 | ·114 | 1·676 |
| 130 | 4·502 | ·150 | 2·205 |
| 140 | 5·858 | ·196 | 2·883 |
| 150 | 7·546 | ·252 | 3·705 |
| 160 | 9·628 | ·322 | 4·734 |
| 170 | 12·18 | ·407 | 5·984 |
| 180 | 15·27 | ·510 | 7·498 |
| 190 | 19·01 | ·635 | 9·336 |
| 200 | 23·46 | ·784 | 11·53 |
| 210 | 29·92 | 1·000 | 14·706 |
| 220 | 35·01 | 1·170 | 17·19 |
| 230 | 42·34 | 1·415 | 20·80 |
| 240 | 50·89 | 1·701 | 25·01 |
| 250 | 60·81 | 2·032 | 29·87 |
| 260 | 72·27 | 2·415 | 35·50 |
| 270 | 85·41 | 2·855 | 41·97 |
| 280 | 100·4 | 3·356 | 49·34 |
| 290 | 117·5 | 3·927 | 57·73 |
| 300 | 136·8 | 4·572 | 67·22 |
| 310 | 158·6 | 5·301 | 77·94 |
| 320 | 183·1 | 6·120 | 89·98 |
| 330 | 210·5 | 7·035 | 103·4 |
| 340 | 241·1 | 8·058 | 118·5 |
| 350 | 275·0 | 9·193 | 135·2 |
| 360 | 312·6 | 10·45 | 153·6 |
| 370 | 354·0 | 11·83 | 173·9 |
| 380 | 399·6 | 13·35 | 196·3 |
| 390 | 449·6 | 15·02 | 220·8 |
| 400 | 504·4 | 16·86 | 247·9 |
| 410 | 563·9 | 18·84 | 277·0 |
| 420 | 628·8 | 21·01 | 309·9 |
| 430 | 699·2 | 23·37 | 343·6 |
| 440 | 775·3 | 25·91 | 380·9 |

TABLE 18.—TENSION OF AQUEOUS VAPOUR IN INCHES OF MERCURY FROM 1° TO 100° F.

| Temperature Fahrenheit. | Inches of Mercury. | Temperature Fahrenheit. | Inches of Mercury. |
|----------------------------|-----------------------|----------------------------|-----------------------|
| 1 | ·046 | 36 | ·212 |
| 2 | ·048 | 37 | ·220 |
| 3 | ·050 | 38 | ·229 |
| 4 | ·052 | 39 | ·238 |
| 5 | ·054 | 40 | ·247 |
| 6 | ·057 | 41 | ·257 |
| 7 | ·060 | 42 | ·267 |
| 8 | ·062 | 43 | ·277 |
| 9 | ·065 | 44 | ·288 |
| 10 | ·068 | 45 | ·299 |
| 11 | ·071 | 46 | ·311 |
| 12 | ·074 | 47 | ·323 |
| 13 | ·078 | 48 | ·335 |
| 14 | ·082 | 49 | ·348 |
| 15 | ·086 | 50 | ·361 |
| 16 | ·090 | 51 | ·374 |
| 17 | ·094 | 52 | ·388 |
| 18 | ·098 | 53 | ·403 |
| 19 | ·103 | 54 | ·418 |
| 20 | ·108 | 55 | ·433 |
| 21 | ·113 | 56 | ·449 |
| 22 | ·118 | 57 | ·465 |
| 23 | ·123 | 58 | ·482 |
| 24 | ·129 | 59 | ·500 |
| 25 | ·135 | 60 | ·518 |
| 26 | ·141 | 61 | ·537 |
| 27 | ·147 | 62 | ·556 |
| 28 | ·153 | 63 | ·576 |
| 29 | ·160 | 64 | ·596 |
| 30 | ·167 | 65 | ·617 |
| 31 | ·174 | 66 | ·639 |
| 32 | ·181 | 67 | ·661 |
| 33 | ·188 | 68 | ·685 |
| 34 | ·196 | 69 | ·708 |
| 35 | ·204 | 70 | ·733 |

TABLE 18—*Continued.*

| Temperature Fahrenheit. | Inches of Mercury. | Temperature Fahrenheit. | Inches of Mercury. |
|----------------------------|-----------------------|----------------------------|-----------------------|
| 71° | ·759 | 86° | 1·242 |
| 72 | ·785 | 87 | 1·282 |
| 73 | ·812 | 88 | 1·323 |
| 74 | ·840 | 89 | 1·366 |
| 75 | ·868 | 90 | 1·401 |
| 76 | ·897 | 91 | 1·455 |
| 77 | ·927 | 92 | 1·501 |
| 78 | ·958 | 93 | 1·548 |
| 79 | ·990 | 94 | 1·596 |
| 80 | 1·023 | 95 | 1·646 |
| 81 | 1·057 | 96 | 1·697 |
| 82 | 1·092 | 97 | 1·751 |
| 83 | 1·128 | 98 | 1·806 |
| 84 | 1·165 | 99 | 1·862 |
| 85 | 1·203 | 100 | 1·918 |

TABLE 19.—BOILING POINT OF WATER AT
DIFFERENT BAROMETRIC PRESSURES.

| Barometric Pressure. | Boiling Point. | Barometric Pressure. | Boiling Point. |
|-------------------------|-------------------|-------------------------|-------------------|
| mm. | | mm. | |
| 710 | 98·11 | 745 | 99·44 |
| 715 | 98·30 | 750 | 99·63 |
| 720 | 98·49 | 755 | 99·82 |
| 725 | 98·69 | 760 | 100·00 |
| 730 | 98·88 | 765 | 100·18 |
| 735 | 99·07 | 770 | 100·37 |
| 740 | 99·26 | 775 | 100·55 |

TABLE 20.—COMPARISON OF THE HYDROMETER DEGREES ACCORDING TO BAUMÉ AND TWADDELL, WITH THE SPECIFIC GRAVITIES.

| B. | Tw. | Spec. Gravity. | B. | Tw. | Spec. Gravity. | B. | Tw. | Spec. Gravity. |
|------|------|----------------|------|------|----------------|------|------|----------------|
| 0 | 0 | 1.000 | 15.4 | 24 | 1.120 | 29.3 | 51 | 1.255 |
| 0.7 | 1 | 1.005 | 16.0 | 25 | 1.125 | 29.7 | 52 | 1.260 |
| 1.0 | 1.4 | 1.007 | 16.5 | 26 | 1.130 | 30.0 | 52.6 | 1.263 |
| 1.4 | 2 | 1.010 | 17.0 | 26.8 | 1.134 | 30.2 | 53 | 1.265 |
| 2.0 | 2.8 | 1.014 | 17.1 | 27 | 1.135 | 30.6 | 54 | 1.270 |
| 2.1 | 3 | 1.015 | 17.7 | 28 | 1.140 | 31.0 | 54.8 | 1.274 |
| 2.7 | 4 | 1.020 | 18.0 | 28.4 | 1.142 | 31.1 | 55 | 1.275 |
| 3.0 | 4.1 | 1.022 | 18.3 | 29 | 1.145 | 31.5 | 56 | 1.280 |
| 3.4 | 5 | 1.025 | 18.8 | 30 | 1.150 | 32.0 | 57 | 1.285 |
| 4.0 | 5.8 | 1.029 | 19.0 | 30.4 | 1.152 | 32.4 | 58 | 1.290 |
| 4.1 | 6 | 1.030 | 19.3 | 31 | 1.155 | 32.8 | 59 | 1.295 |
| 4.7 | 7 | 1.035 | 19.8 | 32 | 1.160 | 33.0 | 59.4 | 1.297 |
| 5.0 | 7.4 | 1.037 | 20.0 | 32.4 | 1.162 | 33.3 | 60 | 1.300 |
| 5.4 | 8 | 1.040 | 20.3 | 33 | 1.165 | 33.7 | 61 | 1.305 |
| 6.0 | 9 | 1.045 | 20.9 | 34 | 1.170 | 34.0 | 61.6 | 1.308 |
| 6.7 | 10 | 1.050 | 21.0 | 34.2 | 1.171 | 34.2 | 62 | 1.310 |
| 7.0 | 10.2 | 1.052 | 21.4 | 35 | 1.175 | 34.6 | 63 | 1.315 |
| 7.4 | 11 | 1.055 | 22.0 | 36 | 1.180 | 35.0 | 64 | 1.320 |
| 8.0 | 12 | 1.060 | 22.5 | 37 | 1.185 | 35.4 | 65 | 1.325 |
| 8.7 | 13 | 1.065 | 23.0 | 38 | 1.190 | 35.8 | 66 | 1.330 |
| 9.0 | 13.4 | 1.067 | 23.5 | 39 | 1.195 | 36.0 | 66.4 | 1.332 |
| 9.4 | 14 | 1.070 | 24.0 | 40 | 1.200 | 36.2 | 67 | 1.335 |
| 10.0 | 15 | 1.075 | 24.5 | 41 | 1.205 | 36.6 | 68 | 1.340 |
| 10.6 | 16 | 1.080 | 25.0 | 42 | 1.210 | 37.0 | 69 | 1.345 |
| 11.0 | 16.6 | 1.083 | 25.5 | 43 | 1.215 | 37.4 | 70 | 1.350 |
| 11.2 | 17 | 1.085 | 26.0 | 44 | 1.220 | 37.8 | 71 | 1.355 |
| 11.9 | 18 | 1.090 | 26.4 | 45 | 1.225 | 38.0 | 71.4 | 1.357 |
| 12.0 | 18.2 | 1.091 | 26.9 | 46 | 1.230 | 38.2 | 72 | 1.360 |
| 12.4 | 19 | 1.095 | 27.0 | 46.2 | 1.231 | 38.6 | 73 | 1.365 |
| 13.0 | 20 | 1.100 | 27.4 | 47 | 1.235 | 39.0 | 74 | 1.370 |
| 13.6 | 21 | 1.105 | 27.9 | 48 | 1.240 | 39.4 | 75 | 1.375 |
| 14.0 | 21.6 | 1.108 | 28.0 | 48.2 | 1.241 | 39.8 | 76 | 1.380 |
| 14.2 | 22 | 1.110 | 28.4 | 49 | 1.245 | 40.0 | 76.6 | 1.383 |
| 14.9 | 23 | 1.115 | 28.8 | 50 | 1.250 | 40.1 | 77 | 1.385 |
| 15.0 | 23.2 | 1.116 | 29.0 | 50.4 | 1.252 | 40.5 | 78 | 1.390 |

N.B.—The Baumé degrees are calculated by the formula $d = \frac{144.3}{144.3 - n}$, where n is the degree on the Baumé scale and d the specific gravity. On this Baumé scale, water at 15° C. = 0° and sulphuric acid of 1.842 = 66°. This is the Baumé's hydrometer, mostly used on the Continent of Europe, but other scales are in use there as well, and quite another scale for Baumé's hydrometer is used in America.

TABLE 20—Continued.

| B. | Tw. | Spec. Gravity. | B. | Tw. | Spec. Gravity. | B. | Tw. | Spec. Gravity. |
|------|------|-------------------|------|-------|-------------------|------|-------|-------------------|
| 40.8 | 79 | 1.395 | 50.9 | 109 | 1.545 | 59.5 | 140 | 1.700 |
| 41.0 | 79.4 | 1.397 | 51.0 | 109.2 | 1.546 | 59.7 | 141 | 1.705 |
| 41.2 | 80 | 1.400 | 51.2 | 110 | 1.550 | 60.0 | 142 | 1.710 |
| 41.6 | 81 | 1.405 | 51.5 | 111 | 1.555 | 60.2 | 143 | 1.715 |
| 42.0 | 82 | 1.410 | 51.8 | 112 | 1.560 | 60.4 | 144 | 1.720 |
| 42.3 | 83 | 1.415 | 52.0 | 112.6 | 1.563 | 60.6 | 145 | 1.725 |
| 42.7 | 84 | 1.420 | 52.1 | 113 | 1.565 | 60.9 | 146 | 1.730 |
| 43.0 | 84.8 | 1.424 | 52.4 | 114 | 1.570 | 61.0 | 146.4 | 1.732 |
| 43.1 | 85 | 1.425 | 52.7 | 115 | 1.575 | 61.1 | 147 | 1.735 |
| 43.4 | 86 | 1.430 | 53.0 | 116 | 1.580 | 61.4 | 148 | 1.740 |
| 43.8 | 87 | 1.435 | 53.3 | 117 | 1.585 | 61.6 | 149 | 1.745 |
| 44.0 | 87.6 | 1.438 | 53.6 | 118 | 1.590 | 61.8 | 150 | 1.750 |
| 44.1 | 88 | 1.440 | 53.9 | 119 | 1.595 | 62.0 | 150.6 | 1.753 |
| 44.4 | 89 | 1.445 | 54.0 | 119.4 | 1.597 | 62.1 | 151 | 1.755 |
| 44.8 | 90 | 1.450 | 54.1 | 120 | 1.600 | 62.3 | 152 | 1.760 |
| 45.0 | 90.6 | 1.453 | 54.4 | 121 | 1.605 | 62.5 | 153 | 1.765 |
| 45.1 | 91 | 1.455 | 54.7 | 122 | 1.610 | 62.8 | 154 | 1.770 |
| 45.4 | 92 | 1.460 | 55.0 | 123 | 1.615 | 63.0 | 155 | 1.775 |
| 45.8 | 93 | 1.465 | 55.2 | 124 | 1.620 | 63.2 | 156 | 1.780 |
| 46.0 | 93.6 | 1.468 | 55.5 | 125 | 1.625 | 63.5 | 157 | 1.785 |
| 46.1 | 94 | 1.470 | 55.8 | 126 | 1.630 | 63.7 | 158 | 1.790 |
| 46.4 | 95 | 1.475 | 56.0 | 127 | 1.635 | 64.0 | 159 | 1.795 |
| 46.8 | 96 | 1.480 | 56.3 | 128 | 1.640 | 64.2 | 160 | 1.800 |
| 47.0 | 96.6 | 1.483 | 56.6 | 129 | 1.645 | 64.4 | 161 | 1.805 |
| 47.1 | 97 | 1.485 | 56.9 | 130 | 1.650 | 64.6 | 162 | 1.810 |
| 47.4 | 98 | 1.490 | 57.0 | 130.4 | 1.652 | 64.8 | 163 | 1.815 |
| 47.8 | 99 | 1.495 | 57.1 | 131 | 1.655 | 65.0 | 164 | 1.820 |
| 48.0 | 99.6 | 1.498 | 57.4 | 132 | 1.660 | 65.2 | 165 | 1.825 |
| 48.1 | 100 | 1.500 | 57.7 | 133 | 1.665 | 65.5 | 166 | 1.830 |
| 48.4 | 101 | 1.505 | 57.9 | 134 | 1.670 | 65.7 | 167 | 1.835 |
| 48.7 | 102 | 1.510 | 58.0 | 134.2 | 1.671 | 65.9 | 168 | 1.840 |
| 49.0 | 103 | 1.515 | 58.2 | 135 | 1.675 | 66.0 | 168.4 | 1.842 |
| 49.4 | 104 | 1.520 | 58.4 | 136 | 1.680 | 66.1 | 169 | 1.845 |
| 49.7 | 105 | 1.525 | 58.7 | 137 | 1.685 | 66.3 | 170 | 1.850 |
| 50.0 | 106 | 1.530 | 58.9 | 138 | 1.690 | 66.5 | 171 | 1.855 |
| 50.3 | 107 | 1.535 | 59.0 | 138.2 | 1.691 | 66.7 | 172 | 1.860 |
| 50.6 | 108 | 1.540 | 59.2 | 139 | 1.695 | 67.0 | 173 | 1.865 |

TABLE 21.—MATHEMATICAL TABLES.

Circumference and area of circles, squares, cubes, square and cube roots.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|-----|--------------|--------------------------|-------|---------|------------|---------------|
| 1.0 | 3.142 | 0.7854 | 1.000 | 1.000 | 1.0000 | 1.0000 |
| 1.1 | 3.456 | 0.9503 | 1.210 | 1.331 | 1.0488 | 1.0323 |
| 1.2 | 3.770 | 1.1310 | 1.440 | 1.728 | 1.0955 | 1.0627 |
| 1.3 | 4.084 | 1.3273 | 1.690 | 2.197 | 1.1402 | 1.0914 |
| 1.4 | 4.398 | 1.5394 | 1.960 | 2.744 | 1.1832 | 1.1187 |
| 1.5 | 4.712 | 1.7672 | 2.250 | 3.375 | 1.2247 | 1.1447 |
| 1.6 | 5.027 | 2.0106 | 2.560 | 4.096 | 1.2649 | 1.1696 |
| 1.7 | 5.341 | 2.2698 | 2.890 | 4.913 | 1.3038 | 1.1935 |
| 1.8 | 5.655 | 2.5447 | 3.240 | 5.832 | 1.3416 | 1.2164 |
| 1.9 | 5.969 | 2.8353 | 3.610 | 6.859 | 1.3784 | 1.2386 |
| 2.0 | 6.283 | 3.1416 | 4.000 | 8.000 | 1.4142 | 1.2599 |
| 2.1 | 6.597 | 3.4636 | 4.410 | 9.261 | 1.4491 | 1.2806 |
| 2.2 | 6.912 | 3.8013 | 4.840 | 10.648 | 1.4832 | 1.3006 |
| 2.3 | 7.226 | 4.1548 | 5.290 | 12.167 | 1.5166 | 1.3200 |
| 2.4 | 7.540 | 4.5239 | 5.760 | 13.824 | 1.5492 | 1.3389 |
| 2.5 | 7.854 | 4.9087 | 6.250 | 15.625 | 1.5811 | 1.3572 |
| 2.6 | 8.168 | 5.3093 | 6.760 | 17.576 | 1.6125 | 1.3751 |
| 2.7 | 8.482 | 5.7256 | 7.290 | 19.683 | 1.6432 | 1.3925 |
| 2.8 | 8.797 | 6.1575 | 7.840 | 21.952 | 1.6733 | 1.4095 |
| 2.9 | 9.111 | 6.6052 | 8.410 | 24.389 | 1.7029 | 1.4260 |
| 3.0 | 9.425 | 7.0686 | 9.00 | 27.000 | 1.7321 | 1.4422 |
| 3.1 | 9.739 | 7.5477 | 9.61 | 29.791 | 1.7607 | 1.4581 |
| 3.2 | 10.053 | 8.0425 | 10.24 | 32.768 | 1.7889 | 1.4736 |
| 3.3 | 10.367 | 8.5530 | 10.89 | 35.937 | 1.8166 | 1.4888 |
| 3.4 | 10.681 | 9.0792 | 11.56 | 39.304 | 1.8439 | 1.5037 |
| 3.5 | 10.996 | 9.6211 | 12.25 | 42.875 | 1.8708 | 1.5183 |
| 3.6 | 11.310 | 10.179 | 12.96 | 46.656 | 1.8974 | 1.5326 |
| 3.7 | 11.624 | 10.752 | 13.69 | 50.653 | 1.9235 | 1.5467 |
| 3.8 | 11.938 | 11.341 | 14.44 | 54.872 | 1.9494 | 1.5605 |
| 3.9 | 12.252 | 11.946 | 15.21 | 59.319 | 1.9748 | 1.5741 |
| 4.0 | 12.566 | 12.566 | 16.00 | 64.000 | 2.0000 | 1.5874 |
| 4.1 | 12.881 | 13.203 | 16.81 | 68.921 | 2.0249 | 1.6005 |
| 4.2 | 13.195 | 13.854 | 17.64 | 74.088 | 2.0491 | 1.6134 |
| 4.3 | 13.509 | 14.522 | 18.49 | 79.507 | 2.0736 | 1.6261 |
| 4.4 | 13.823 | 15.205 | 19.36 | 85.184 | 2.0976 | 1.6386 |
| 4.5 | 14.137 | 15.904 | 20.25 | 91.125 | 2.1213 | 1.6510 |
| 4.6 | 14.451 | 16.619 | 21.16 | 97.336 | 2.1448 | 1.6631 |
| 4.7 | 14.765 | 17.349 | 22.09 | 103.823 | 2.1680 | 1.6751 |

TABLE 21—*Continued.*

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|-----|--------------|--------------------------|-------|---------|------------|---------------|
| 4.8 | 15.080 | 18.096 | 23.04 | 110.592 | 2.1909 | 1.6869 |
| 4.9 | 15.391 | 18.857 | 24.01 | 117.649 | 2.2136 | 1.6985 |
| 5.0 | 15.708 | 19.635 | 25.00 | 125.000 | 2.2361 | 1.7100 |
| 5.1 | 16.022 | 20.428 | 26.01 | 132.651 | 2.2583 | 1.7213 |
| 5.2 | 16.336 | 21.237 | 27.04 | 140.608 | 2.2804 | 1.7325 |
| 5.3 | 16.650 | 22.062 | 28.09 | 148.877 | 2.3022 | 1.7435 |
| 5.4 | 16.965 | 22.902 | 29.16 | 157.464 | 2.3238 | 1.7544 |
| 5.5 | 17.279 | 23.758 | 30.25 | 166.375 | 2.3452 | 1.7652 |
| 5.6 | 17.593 | 24.630 | 31.36 | 175.616 | 2.3664 | 1.7758 |
| 5.7 | 17.907 | 25.518 | 32.49 | 185.193 | 2.3875 | 1.7863 |
| 5.8 | 18.221 | 26.421 | 33.64 | 195.112 | 2.4083 | 1.7967 |
| 5.9 | 18.535 | 27.340 | 34.81 | 205.379 | 2.4290 | 1.8070 |
| 6.0 | 18.850 | 28.274 | 36.00 | 216.000 | 2.4495 | 1.8171 |
| 6.1 | 19.164 | 29.225 | 37.21 | 226.981 | 2.4698 | 1.8272 |
| 6.2 | 19.478 | 30.191 | 38.44 | 238.328 | 2.4900 | 1.8371 |
| 6.3 | 19.792 | 31.173 | 39.69 | 250.047 | 2.5100 | 1.8469 |
| 6.4 | 20.106 | 32.170 | 40.96 | 262.144 | 2.5298 | 1.8566 |
| 6.5 | 20.420 | 33.183 | 42.25 | 274.625 | 2.5495 | 1.8663 |
| 6.6 | 20.735 | 34.212 | 43.56 | 287.496 | 2.5691 | 1.8758 |
| 6.7 | 21.049 | 35.257 | 44.89 | 300.763 | 2.5884 | 1.8852 |
| 6.8 | 21.363 | 36.317 | 46.24 | 314.432 | 2.6077 | 1.8945 |
| 6.9 | 21.677 | 37.393 | 47.61 | 328.509 | 2.6268 | 1.9038 |
| 7.0 | 21.991 | 38.485 | 49.00 | 343.000 | 2.6458 | 1.9129 |
| 7.1 | 22.305 | 39.592 | 50.41 | 357.911 | 2.6646 | 1.9220 |
| 7.2 | 22.619 | 40.715 | 51.84 | 373.248 | 2.6833 | 1.9310 |
| 7.3 | 22.934 | 41.854 | 53.29 | 389.017 | 2.7019 | 1.9399 |
| 7.4 | 23.248 | 43.008 | 54.76 | 405.224 | 2.7203 | 1.9487 |
| 7.5 | 23.562 | 44.179 | 56.25 | 421.875 | 2.7386 | 1.9574 |
| 7.6 | 23.876 | 45.365 | 57.76 | 438.976 | 2.7568 | 1.9661 |
| 7.7 | 24.190 | 46.566 | 59.29 | 456.533 | 2.7749 | 1.9747 |
| 7.8 | 24.504 | 47.784 | 60.84 | 474.552 | 2.7929 | 1.9832 |
| 7.9 | 24.819 | 49.017 | 62.41 | 493.039 | 2.8107 | 1.9916 |
| 8.0 | 25.133 | 50.266 | 64.00 | 512.000 | 2.8284 | 2.0000 |
| 8.1 | 25.447 | 51.530 | 65.61 | 531.441 | 2.8461 | 2.0083 |
| 8.2 | 25.761 | 52.810 | 67.24 | 551.368 | 2.8636 | 2.0165 |
| 8.3 | 26.075 | 54.106 | 68.89 | 571.787 | 2.8810 | 2.0247 |
| 8.4 | 26.389 | 55.418 | 70.56 | 592.704 | 2.8983 | 2.0328 |

TABLE 21---Continued.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|--------|----------|------------|---------------|
| 8.5 | 26.704 | 56.745 | 72.25 | 614.125 | 2.9155 | 2.0408 |
| 8.6 | 27.018 | 58.088 | 73.96 | 636.056 | 2.9326 | 2.0488 |
| 8.7 | 27.332 | 59.447 | 75.69 | 658.503 | 2.9496 | 2.0567 |
| 8.8 | 27.646 | 60.821 | 77.44 | 681.472 | 2.9665 | 2.0646 |
| 8.9 | 27.960 | 62.211 | 79.21 | 704.969 | 2.9833 | 2.0724 |
| 9.0 | 28.274 | 63.617 | 81.00 | 729.000 | 3.0000 | 2.0801 |
| 9.1 | 28.588 | 65.039 | 82.81 | 753.571 | 3.0166 | 2.0878 |
| 9.2 | 28.903 | 66.476 | 84.64 | 778.688 | 3.0332 | 2.0954 |
| 9.3 | 29.217 | 67.929 | 86.49 | 804.357 | 3.0496 | 2.1029 |
| 9.4 | 29.531 | 69.398 | 88.36 | 830.584 | 3.0659 | 2.1105 |
| 9.5 | 29.845 | 70.882 | 90.25 | 857.375 | 3.0822 | 2.1179 |
| 9.6 | 30.159 | 72.382 | 92.16 | 884.736 | 3.0984 | 2.1253 |
| 9.7 | 30.473 | 73.898 | 94.09 | 912.673 | 3.1145 | 2.1327 |
| 9.8 | 30.788 | 75.430 | 96.04 | 941.192 | 3.1305 | 2.1400 |
| 9.9 | 31.102 | 76.977 | 98.01 | 970.299 | 3.1464 | 2.1472 |
| 10.0 | 31.416 | 78.540 | 100.00 | 1000.000 | 3.1623 | 2.1544 |
| 10.1 | 31.730 | 80.119 | 102.01 | 1030.301 | 3.1780 | 2.1616 |
| 10.2 | 32.044 | 81.713 | 104.04 | 1061.208 | 3.1937 | 2.1687 |
| 10.3 | 32.358 | 83.323 | 106.09 | 1092.727 | 3.2094 | 2.1757 |
| 10.4 | 32.673 | 84.949 | 108.16 | 1124.864 | 3.2249 | 2.1828 |
| 10.5 | 32.987 | 86.590 | 110.25 | 1157.625 | 3.2404 | 2.1897 |
| 10.6 | 33.301 | 88.247 | 112.36 | 1191.016 | 3.2558 | 2.1967 |
| 10.7 | 33.615 | 89.920 | 114.49 | 1225.043 | 3.2711 | 2.2036 |
| 10.8 | 33.929 | 91.609 | 116.64 | 1259.712 | 3.2863 | 2.2104 |
| 10.9 | 34.243 | 93.313 | 118.81 | 1295.029 | 3.3015 | 2.2172 |
| 11.0 | 34.558 | 95.033 | 121.00 | 1331.000 | 3.3166 | 2.2239 |
| 11.1 | 34.872 | 96.769 | 123.21 | 1367.631 | 3.3317 | 2.2307 |
| 11.2 | 35.186 | 98.520 | 125.44 | 1404.928 | 3.3466 | 2.2374 |
| 11.3 | 35.500 | 100.29 | 127.69 | 1442.897 | 3.3615 | 2.2441 |
| 11.4 | 35.814 | 102.07 | 129.96 | 1481.544 | 3.3754 | 2.2506 |
| 11.5 | 36.128 | 103.87 | 132.25 | 1520.875 | 3.3912 | 2.2572 |
| 11.6 | 36.442 | 105.68 | 134.56 | 1560.896 | 3.4059 | 2.2637 |
| 11.7 | 36.757 | 107.51 | 136.89 | 1601.613 | 3.4205 | 2.2702 |
| 11.8 | 37.071 | 109.36 | 139.24 | 1643.032 | 3.4351 | 2.2766 |
| 11.9 | 37.385 | 111.22 | 141.61 | 1685.159 | 3.4496 | 2.2831 |
| 12.0 | 37.699 | 113.10 | 144.00 | 1728.000 | 3.4641 | 2.2894 |
| 12.1 | 38.013 | 114.99 | 146.41 | 1771.561 | 3.4785 | 2.2957 |
| 12.2 | 38.327 | 116.90 | 148.84 | 1815.848 | 3.4928 | 2.3021 |

TABLE 21—Continued.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|--------|----------|------------|---------------|
| 12·3 | 38·642 | 118·82 | 151·29 | 1860·867 | 3·5071 | 2·3084 |
| 12·4 | 38·956 | 120·76 | 153·76 | 1906·624 | 3·5214 | 2·3146 |
| 12·5 | 39·270 | 122·72 | 156·15 | 1953·125 | 3·5355 | 2·3203 |
| 12·6 | 39·584 | 124·69 | 158·76 | 2000·376 | 3·5496 | 2·3270 |
| 12·7 | 39·898 | 126·68 | 161·29 | 2048·383 | 3·5637 | 2·3331 |
| 12·8 | 40·212 | 128·68 | 163·84 | 2097·152 | 3·5777 | 2·3392 |
| 12·9 | 40·527 | 130·70 | 166·41 | 2146·659 | 3·5917 | 2·3453 |
| 13·0 | 40·841 | 132·73 | 169·00 | 2197·000 | 3·6056 | 2·3513 |
| 13·1 | 41·155 | 134·78 | 171·61 | 2248·091 | 3·6194 | 2·3573 |
| 13·2 | 41·469 | 136·85 | 174·24 | 2299·968 | 3·6332 | 2·3633 |
| 13·3 | 41·783 | 138·93 | 176·89 | 2352·637 | 3·6469 | 2·3693 |
| 13·4 | 42·097 | 141·03 | 179·56 | 2406·104 | 3·6606 | 2·3752 |
| 13·5 | 42·412 | 143·14 | 182·25 | 2460·375 | 3·6742 | 2·3811 |
| 13·6 | 42·726 | 145·27 | 184·96 | 2515·456 | 3·6878 | 2·3870 |
| 13·7 | 43·040 | 147·41 | 187·69 | 2571·353 | 3·7013 | 2·3928 |
| 13·8 | 43·354 | 149·57 | 190·44 | 2628·072 | 3·7148 | 2·3986 |
| 13·9 | 43·668 | 151·75 | 193·21 | 2685·619 | 3·7283 | 2·4044 |
| 14·0 | 43·892 | 153·94 | 196·00 | 2744·000 | 3·7417 | 2·4101 |
| 14·1 | 44·296 | 156·15 | 198·81 | 2803·221 | 3·7550 | 2·4159 |
| 14·2 | 44·611 | 158·37 | 201·64 | 2863·283 | 3·7683 | 2·4216 |
| 14·3 | 44·925 | 160·61 | 204·49 | 2924·207 | 3·7815 | 2·4272 |
| 14·4 | 45·239 | 162·86 | 207·36 | 2985·984 | 3·7947 | 2·4329 |
| 14·5 | 45·553 | 165·13 | 210·25 | 3048·625 | 3·8079 | 2·4385 |
| 14·6 | 45·867 | 167·42 | 213·16 | 3112·136 | 3·8210 | 2·4441 |
| 14·7 | 46·181 | 169·72 | 216·09 | 3176·523 | 3·8341 | 2·4497 |
| 11·8 | 46·496 | 172·03 | 219·04 | 3241·792 | 3·8471 | 2·4552 |
| 11·9 | 46·810 | 174·37 | 222·01 | 3307·919 | 3·8600 | 2·4607 |
| 15·0 | 47·124 | 176·72 | 225·00 | 3375·000 | 3·8730 | 2·4662 |
| 15·1 | 47·438 | 179·08 | 228·09 | 3442·951 | 3·8859 | 2·4717 |
| 15·2 | 47·752 | 181·46 | 231·04 | 3511·808 | 3·8987 | 2·4772 |
| 15·3 | 48·066 | 183·85 | 234·09 | 3581·577 | 3·9115 | 2·4825 |
| 15·4 | 48·381 | 186·27 | 237·16 | 3652·264 | 3·9243 | 2·4879 |
| 15·5 | 48·695 | 188·69 | 240·25 | 3723·875 | 3·9370 | 2·4933 |
| 15·6 | 49·009 | 191·13 | 243·36 | 3796·416 | 3·9497 | 2·4986 |
| 15·7 | 49·323 | 193·59 | 246·49 | 3869·893 | 3·9623 | 2·5039 |
| 15·8 | 49·637 | 196·07 | 249·64 | 3944·312 | 3·9749 | 2·5092 |
| 15·9 | 49·951 | 198·56 | 252·81 | 4019·679 | 3·9875 | 2·5146 |

TABLE 21—*Continued.*

| n | πn ○ | $\frac{\pi n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|--------|----------|------------|---------------|
| 16.0 | 50.265 | 201.06 | 256.00 | 4096.000 | 4.0000 | 2.5198 |
| 16.1 | 50.580 | 203.58 | 259.21 | 4173.281 | 4.0125 | 2.5251 |
| 16.2 | 50.894 | 206.13 | 262.44 | 4251.528 | 4.0249 | 2.5303 |
| 16.3 | 51.208 | 208.67 | 265.69 | 4330.747 | 4.0373 | 2.5355 |
| 16.4 | 51.522 | 211.24 | 268.96 | 4410.914 | 4.0497 | 2.5406 |
| 16.5 | 51.836 | 213.83 | 272.25 | 4492.125 | 4.0620 | 2.5458 |
| 16.6 | 52.150 | 216.42 | 275.56 | 4574.296 | 4.0743 | 2.5509 |
| 16.7 | 52.465 | 219.04 | 278.89 | 4657.463 | 4.0866 | 2.5561 |
| 16.8 | 52.779 | 221.67 | 282.24 | 4741.632 | 4.0988 | 2.5612 |
| 16.9 | 53.093 | 224.32 | 285.61 | 4826.809 | 4.1110 | 2.5663 |
| 17.0 | 53.407 | 226.98 | 289.00 | 4913.000 | 4.1231 | 2.5713 |
| 17.1 | 53.721 | 229.66 | 292.41 | 5000.211 | 4.1352 | 2.5763 |
| 17.2 | 54.035 | 232.35 | 295.84 | 5088.448 | 4.1473 | 2.5813 |
| 17.3 | 54.350 | 235.06 | 299.29 | 5177.717 | 4.1593 | 2.5863 |
| 17.4 | 54.664 | 237.79 | 302.76 | 5268.024 | 4.1713 | 2.5913 |
| 17.5 | 54.978 | 240.53 | 306.25 | 5359.375 | 4.1833 | 2.5963 |
| 17.6 | 55.292 | 243.29 | 309.76 | 5451.776 | 4.1952 | 2.6012 |
| 17.7 | 55.606 | 246.06 | 313.29 | 5545.233 | 4.2071 | 2.6061 |
| 17.8 | 55.920 | 248.85 | 316.84 | 5639.752 | 4.2190 | 2.6109 |
| 17.9 | 56.235 | 251.65 | 320.41 | 5735.339 | 4.2308 | 2.6158 |
| 18.0 | 56.549 | 254.47 | 324.00 | 5832.000 | 4.2426 | 2.6207 |
| 18.1 | 56.863 | 257.30 | 327.61 | 5929.741 | 4.2544 | 2.6256 |
| 18.2 | 57.177 | 260.16 | 331.24 | 6028.568 | 4.2661 | 2.6304 |
| 18.3 | 57.491 | 263.02 | 334.89 | 6128.487 | 4.2778 | 2.6352 |
| 18.4 | 57.805 | 265.90 | 338.56 | 6229.504 | 4.2895 | 2.6400 |
| 18.5 | 58.119 | 268.80 | 342.25 | 6331.625 | 4.3012 | 2.6448 |
| 18.6 | 58.434 | 271.72 | 345.96 | 6434.856 | 4.3128 | 2.6495 |
| 18.7 | 58.748 | 274.65 | 349.69 | 6539.203 | 4.3243 | 2.6543 |
| 18.8 | 59.062 | 277.59 | 353.44 | 6644.672 | 4.3359 | 2.6590 |
| 18.9 | 59.376 | 280.55 | 357.21 | 6751.269 | 4.3474 | 2.6637 |
| 19.0 | 59.690 | 283.53 | 361.00 | 6859.000 | 4.3589 | 2.6684 |
| 19.1 | 60.004 | 286.52 | 364.81 | 6967.871 | 4.3703 | 2.6731 |
| 19.2 | 60.319 | 289.53 | 368.64 | 7077.888 | 4.3818 | 2.6777 |
| 19.3 | 60.633 | 292.55 | 372.49 | 7189.057 | 4.3942 | 2.6824 |
| 19.4 | 60.947 | 295.59 | 376.36 | 7301.384 | 4.4045 | 2.6869 |
| 19.5 | 61.261 | 298.65 | 380.25 | 7414.875 | 4.4159 | 2.6916 |
| 19.6 | 61.575 | 301.72 | 384.16 | 7529.536 | 4.4272 | 2.6962 |
| 19.7 | 61.889 | 304.81 | 388.09 | 7642.373 | 4.4385 | 2.7008 |

TABLE 21—Continued.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n' | n^2 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|--------|-----------|------------|---------------|
| 19·8 | 62·204 | 307·91 | 392·04 | 7762·392 | 4·4497 | 2·7053 |
| 19·9 | 62·518 | 311·03 | 396·01 | 7880·599 | 4·4609 | 2·7098 |
| 20·0 | 62·832 | 314·16 | 400·00 | 8000·000 | 4·4721 | 2·7144 |
| 20·1 | 63·146 | 317·31 | 404·01 | 8120·601 | 4·4833 | 2·7189 |
| 20·2 | 63·460 | 320·47 | 408·01 | 8242·408 | 4·4944 | 2·7234 |
| 20·3 | 63·774 | 323·66 | 412·09 | 8365·427 | 4·5055 | 2·7279 |
| 20·4 | 64·088 | 326·86 | 416·16 | 8489·664 | 4·5166 | 2·7324 |
| 20·5 | 64·403 | 330·06 | 420·25 | 8615·125 | 4·5277 | 2·7368 |
| 20·6 | 64·717 | 333·29 | 424·36 | 8741·816 | 4·5387 | 2·7413 |
| 20·7 | 65·031 | 336·54 | 428·49 | 8869·743 | 4·5497 | 2·7457 |
| 20·8 | 65·345 | 339·80 | 432·64 | 8998·912 | 4·5607 | 2·7502 |
| 20·9 | 65·659 | 313·07 | 436·81 | 9129·329 | 4·5716 | 2·7545 |
| 21·0 | 65·973 | 316·36 | 441·00 | 9261·000 | 4·5826 | 2·7589 |
| 21·1 | 66·288 | 319·67 | 445·21 | 9393·931 | 4·5935 | 2·7633 |
| 21·2 | 66·602 | 352·99 | 449·44 | 9528·128 | 4·6043 | 2·7676 |
| 21·3 | 66·916 | 356·33 | 453·69 | 9663·597 | 4·6152 | 2·7720 |
| 21·4 | 67·230 | 359·68 | 457·96 | 9800·344 | 4·6260 | 2·7763 |
| 21·5 | 67·544 | 363·05 | 462·25 | 9938·375 | 4·6368 | 2·7806 |
| 21·6 | 67·858 | 366·44 | 466·56 | 10077·696 | 4·6476 | 2·7849 |
| 21·7 | 68·173 | 369·84 | 470·89 | 10218·313 | 4·6583 | 2·7893 |
| 21·8 | 68·487 | 373·25 | 475·24 | 10360·232 | 4·6690 | 2·7935 |
| 21·9 | 68·801 | 376·69 | 479·41 | 10503·459 | 4·6797 | 2·7978 |
| 22·0 | 69·115 | 380·13 | 484·00 | 10648·000 | 4·6904 | 2·8021 |
| 22·1 | 69·429 | 383·60 | 488·41 | 10793·861 | 4·7011 | 2·8063 |
| 22·2 | 69·743 | 387·08 | 492·84 | 10941·048 | 4·7117 | 2·8105 |
| 22·3 | 70·058 | 390·57 | 497·29 | 11089·567 | 4·7223 | 2·8147 |
| 22·4 | 70·372 | 394·08 | 501·76 | 11239·424 | 4·7329 | 2·8189 |
| 22·5 | 70·686 | 397·61 | 506·25 | 11390·625 | 4·7434 | 2·8231 |
| 22·6 | 71·000 | 401·15 | 510·76 | 11543·176 | 4·7539 | 2·8273 |
| 22·7 | 71·314 | 404·71 | 515·29 | 11697·083 | 4·7644 | 2·8314 |
| 22·8 | 71·628 | 408·28 | 519·84 | 11852·352 | 4·7749 | 2·8356 |
| 22·9 | 71·942 | 411·87 | 524·41 | 12008·989 | 4·7854 | 2·8397 |
| 23·0 | 72·257 | 415·48 | 529·00 | 12167·000 | 4·7958 | 2·8438 |
| 23·1 | 72·571 | 419·10 | 533·61 | 12326·391 | 4·8062 | 2·8479 |
| 23·2 | 72·885 | 422·73 | 538·24 | 12487·168 | 4·8166 | 2·8521 |
| 23·3 | 73·199 | 426·39 | 542·89 | 12649·337 | 4·8270 | 2·8562 |
| 23·4 | 73·513 | 430·05 | 547·56 | 12812·904 | 4·8373 | 2·8603 |

TABLE 21—*Continued.*

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|--------|-----------|------------|---------------|
| 23.5 | 73.827 | 433.74 | 552.25 | 12977.875 | 4.8477 | 2.8643 |
| 23.6 | 74.142 | 437.44 | 556.96 | 13144.256 | 4.8580 | 2.8684 |
| 23.7 | 74.456 | 441.15 | 561.69 | 13312.053 | 4.8683 | 2.8724 |
| 23.8 | 74.770 | 444.88 | 566.44 | 13481.272 | 4.8785 | 2.8765 |
| 23.9 | 75.084 | 448.63 | 571.21 | 13651.919 | 4.8888 | 2.8805 |
| 24.0 | 75.398 | 452.39 | 576.00 | 13824.000 | 4.8990 | 2.8845 |
| 24.1 | 75.712 | 456.17 | 580.81 | 13997.521 | 4.9092 | 2.8885 |
| 24.2 | 76.027 | 459.96 | 585.64 | 14172.488 | 4.9192 | 2.8925 |
| 24.3 | 76.341 | 463.77 | 590.49 | 14348.907 | 4.9295 | 2.8965 |
| 24.4 | 76.655 | 467.60 | 595.36 | 14526.784 | 4.9396 | 2.9004 |
| 24.5 | 76.969 | 471.44 | 600.25 | 14706.125 | 4.9497 | 2.9044 |
| 24.6 | 77.283 | 475.29 | 605.16 | 14886.936 | 4.9598 | 2.9083 |
| 24.7 | 77.597 | 479.16 | 610.09 | 15069.223 | 4.9699 | 2.9123 |
| 24.8 | 77.911 | 483.05 | 615.04 | 15252.992 | 4.9799 | 2.9162 |
| 24.9 | 78.226 | 486.96 | 620.01 | 15438.249 | 4.9899 | 2.9201 |
| 25.0 | 78.540 | 490.87 | 625.00 | 15625.000 | 5.0000 | 2.9241 |
| 25.1 | 78.854 | 494.81 | 630.01 | 15813.251 | 5.0099 | 2.9279 |
| 25.2 | 79.168 | 498.76 | 635.04 | 16003.008 | 5.0199 | 2.9318 |
| 25.3 | 79.482 | 502.73 | 640.09 | 16194.277 | 5.0299 | 2.9356 |
| 25.4 | 79.796 | 506.71 | 645.16 | 16387.064 | 5.0398 | 2.9395 |
| 25.5 | 80.111 | 510.71 | 650.25 | 16581.375 | 5.0497 | 2.9434 |
| 25.6 | 80.425 | 514.72 | 655.36 | 16777.216 | 5.0596 | 2.9472 |
| 25.7 | 80.739 | 518.75 | 660.49 | 16974.593 | 5.0695 | 2.9510 |
| 25.8 | 81.053 | 522.79 | 665.64 | 17173.512 | 5.0793 | 2.9549 |
| 25.9 | 81.367 | 526.85 | 670.81 | 17373.979 | 5.0892 | 2.9586 |
| 26.0 | 81.681 | 530.93 | 676.00 | 17576.000 | 5.0990 | 2.9624 |
| 26.1 | 81.996 | 535.02 | 681.21 | 17779.581 | 5.1088 | 2.9662 |
| 26.2 | 82.310 | 539.13 | 686.44 | 17984.728 | 5.1185 | 2.9701 |
| 26.3 | 82.624 | 543.25 | 691.69 | 18191.447 | 5.1283 | 2.9738 |
| 26.4 | 82.938 | 547.39 | 696.96 | 18399.744 | 5.1380 | 2.9776 |
| 26.5 | 83.252 | 551.55 | 702.25 | 18609.625 | 5.1478 | 2.9814 |
| 26.6 | 83.566 | 555.72 | 707.56 | 18821.096 | 5.1575 | 2.9851 |
| 26.7 | 83.881 | 559.90 | 712.89 | 19034.163 | 5.1672 | 2.9888 |
| 26.8 | 84.195 | 564.10 | 718.24 | 19248.832 | 5.1768 | 2.9926 |
| 26.9 | 84.509 | 568.32 | 723.61 | 19465.109 | 5.1865 | 2.9963 |
| 27.0 | 84.823 | 572.56 | 729.00 | 19683.000 | 5.1962 | 3.0000 |
| 27.1 | 85.137 | 576.80 | 734.41 | 19902.511 | 5.2057 | 3.0037 |
| 27.2 | 85.451 | 581.07 | 739.84 | 20123.648 | 5.2153 | 3.0074 |

TABLE 21—Continued.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|--------|-----------|------------|---------------|
| 27·3 | 85·765 | 585·35 | 745·29 | 20316·417 | 5·2249 | 3·6111 |
| 27·4 | 86·080 | 589·65 | 750·76 | 20570·824 | 5·2345 | 3·6147 |
| 27·5 | 86·394 | 593·96 | 756·25 | 20796·875 | 5·2440 | 3·6184 |
| 27·6 | 86·708 | 598·29 | 761·76 | 21024·576 | 5·2535 | 3·6221 |
| 27·7 | 87·022 | 602·63 | 767·29 | 21253·933 | 5·2630 | 3·6257 |
| 27·8 | 87·336 | 606·99 | 772·84 | 21484·952 | 5·2725 | 3·6293 |
| 27·9 | 87·650 | 611·36 | 778·41 | 21717·639 | 5·2820 | 3·6330 |
| 28·0 | 87·965 | 615·75 | 784·00 | 21952·000 | 5·2915 | 3·6366 |
| 28·1 | 88·279 | 620·16 | 789·61 | 22188·041 | 5·3009 | 3·6402 |
| 28·2 | 88·593 | 624·58 | 795·24 | 22425·768 | 5·3103 | 3·6438 |
| 28·3 | 88·907 | 629·02 | 800·89 | 22665·187 | 5·3197 | 3·6474 |
| 28·4 | 89·221 | 633·47 | 806·56 | 22906·304 | 5·3291 | 3·6510 |
| 28·5 | 89·535 | 637·94 | 812·25 | 23149·125 | 5·3385 | 3·6546 |
| 28·6 | 89·850 | 642·42 | 817·96 | 23393·656 | 5·3478 | 3·6581 |
| 28·7 | 90·164 | 646·93 | 823·69 | 23639·903 | 5·3572 | 3·6617 |
| 28·8 | 90·478 | 651·44 | 829·44 | 23887·872 | 5·3665 | 3·6652 |
| 28·9 | 90·792 | 655·97 | 835·21 | 24137·569 | 5·3758 | 3·6688 |
| 29·0 | 91·106 | 660·52 | 841·00 | 24389·000 | 5·3852 | 3·6723 |
| 29·1 | 91·420 | 665·08 | 846·81 | 24642·171 | 5·3944 | 3·6758 |
| 29·2 | 91·735 | 669·66 | 852·64 | 24897·088 | 5·4037 | 3·6794 |
| 29·3 | 92·049 | 674·26 | 858·49 | 25153·757 | 5·4129 | 3·6829 |
| 29·4 | 92·363 | 678·87 | 864·36 | 25412·184 | 5·4221 | 3·6864 |
| 29·5 | 92·677 | 683·49 | 870·25 | 25672·375 | 5·4313 | 3·6899 |
| 29·6 | 92·991 | 688·13 | 876·16 | 25934·336 | 5·4405 | 3·6934 |
| 29·7 | 93·305 | 692·79 | 882·09 | 26198·073 | 5·4497 | 3·6968 |
| 29·8 | 93·619 | 697·47 | 888·04 | 26463·592 | 5·4589 | 3·1003 |
| 29·9 | 93·934 | 702·15 | 894·01 | 26730·899 | 5·4680 | 3·1038 |
| 30·0 | 94·248 | 706·86 | 900·00 | 27000·000 | 5·4772 | 3·1072 |
| 30·1 | 94·562 | 711·58 | 906·01 | 27270·901 | 5·4863 | 3·1107 |
| 30·2 | 94·876 | 716·32 | 912·04 | 27543·608 | 5·4954 | 3·1141 |
| 30·3 | 95·190 | 721·07 | 918·09 | 27818·127 | 5·5045 | 3·1176 |
| 30·4 | 95·504 | 725·83 | 924·16 | 28094·464 | 5·5136 | 3·1210 |
| 30·5 | 95·819 | 730·62 | 930·25 | 28372·625 | 5·5226 | 3·1244 |
| 30·6 | 96·133 | 735·42 | 936·36 | 28652·616 | 5·5317 | 3·1278 |
| 30·7 | 96·447 | 740·23 | 942·49 | 28934·443 | 5·5407 | 3·1312 |
| 30·8 | 96·761 | 745·06 | 948·64 | 29218·112 | 5·5497 | 3·1346 |
| 30·9 | 97·075 | 749·91 | 954·81 | 29503·629 | 5·5587 | 3·1380 |

TABLE 21—*Continued.*

| n | πn ○ | $\frac{\pi n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|---------|-----------|------------|---------------|
| 31.0 | 97.389 | 754.77 | 961.00 | 29791.000 | 5.5678 | 3.1414 |
| 31.1 | 97.704 | 759.65 | 967.21 | 30080.231 | 5.5767 | 3.1448 |
| 31.2 | 98.018 | 764.54 | 973.44 | 30371.328 | 5.5857 | 3.1481 |
| 31.3 | 98.332 | 769.45 | 979.69 | 30664.297 | 5.5946 | 3.1515 |
| 31.4 | 98.646 | 774.37 | 985.96 | 30959.144 | 5.6035 | 3.1549 |
| 31.5 | 98.960 | 779.31 | 992.25 | 31255.875 | 5.6124 | 3.1582 |
| 31.6 | 99.274 | 784.27 | 998.56 | 31551.496 | 5.6213 | 3.1615 |
| 31.7 | 99.588 | 789.21 | 1004.89 | 31855.013 | 5.6302 | 3.1648 |
| 31.8 | 99.903 | 794.23 | 1011.24 | 32157.482 | 5.6391 | 3.1681 |
| 31.9 | 100.22 | 799.23 | 1017.61 | 32461.759 | 5.6480 | 3.1715 |
| 32.0 | 100.53 | 804.25 | 1024.00 | 32768.000 | 5.6569 | 3.1748 |
| 32.1 | 100.85 | 809.28 | 1030.41 | 33076.161 | 5.6656 | 3.1781 |
| 32.2 | 101.16 | 814.33 | 1036.84 | 33386.248 | 5.6745 | 3.1814 |
| 32.3 | 101.47 | 819.40 | 1043.29 | 33698.267 | 5.6833 | 3.1847 |
| 32.4 | 101.79 | 824.49 | 1049.76 | 34012.224 | 5.6921 | 3.1880 |
| 32.5 | 102.10 | 829.58 | 1056.25 | 34328.125 | 5.7008 | 3.1913 |
| 32.6 | 102.42 | 834.69 | 1062.76 | 34645.976 | 5.7096 | 3.1945 |
| 32.7 | 102.73 | 839.82 | 1069.29 | 34965.783 | 5.7183 | 3.1978 |
| 32.8 | 103.04 | 844.96 | 1075.84 | 35287.552 | 5.7271 | 3.2010 |
| 32.9 | 103.36 | 850.12 | 1082.41 | 35611.289 | 5.7358 | 3.2043 |
| 33.0 | 103.67 | 855.30 | 1089.00 | 35937.000 | 5.7447 | 3.2075 |
| 33.1 | 103.99 | 860.49 | 1095.61 | 36264.691 | 5.7532 | 3.2108 |
| 33.2 | 104.30 | 865.70 | 1102.24 | 36594.368 | 5.7619 | 3.2140 |
| 33.3 | 104.62 | 870.92 | 1108.89 | 36925.037 | 5.7706 | 3.2172 |
| 33.4 | 104.93 | 876.19 | 1115.56 | 37257.704 | 5.7792 | 3.2204 |
| 33.5 | 105.24 | 881.41 | 1122.25 | 37595.375 | 5.7879 | 3.2237 |
| 33.6 | 105.56 | 886.68 | 1128.96 | 37933.056 | 5.7965 | 3.2269 |
| 33.7 | 105.87 | 891.97 | 1135.69 | 38272.753 | 5.8051 | 3.2301 |
| 33.8 | 106.19 | 897.27 | 1142.44 | 38614.472 | 5.8137 | 3.2332 |
| 33.9 | 106.50 | 902.59 | 1149.21 | 38958.219 | 5.8223 | 3.2364 |
| 34.0 | 106.81 | 907.92 | 1156.00 | 39304.000 | 5.8310 | 3.2396 |
| 34.1 | 107.13 | 913.27 | 1162.81 | 39651.821 | 5.8395 | 3.2424 |
| 34.2 | 107.44 | 918.63 | 1169.64 | 40001.682 | 5.8480 | 3.2460 |
| 34.3 | 107.76 | 924.01 | 1176.49 | 40353.607 | 5.8566 | 3.2491 |
| 34.4 | 108.07 | 929.41 | 1183.36 | 40707.584 | 5.8751 | 3.2522 |
| 34.5 | 108.38 | 934.82 | 1190.25 | 41063.525 | 5.8736 | 3.2554 |
| 34.6 | 108.70 | 940.25 | 1197.16 | 41421.736 | 5.8821 | 3.2586 |
| 34.7 | 109.01 | 945.69 | 1204.09 | 41781.923 | 5.8906 | 3.2617 |

TABLE 21—Continued.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|---------|-----------|------------|---------------|
| 34·8 | 109·33 | 951·15 | 1211·04 | 42144·192 | 5·8991 | 3·2648 |
| 34·9 | 109·64 | 956·62 | 1218·01 | 42508·549 | 5·9076 | 3·2679 |
| 35·0 | 109·96 | 962·11 | 1225·00 | 42875·000 | 5·9161 | 3·2710 |
| 35·1 | 110·27 | 967·62 | 1232·01 | 43243·551 | 5·9245 | 3·2742 |
| 35·2 | 110·58 | 973·14 | 1239·04 | 43614·208 | 5·9326 | 3·2773 |
| 35·3 | 110·90 | 978·68 | 1246·09 | 43986·977 | 5·9413 | 3·2804 |
| 35·4 | 111·21 | 984·23 | 1253·16 | 44361·864 | 5·9497 | 3·2835 |
| 35·5 | 111·53 | 989·80 | 1260·25 | 44738·875 | 5·9581 | 3·2866 |
| 35·6 | 111·84 | 995·38 | 1267·36 | 45118·016 | 5·9665 | 3·2897 |
| 35·7 | 112·15 | 1000·98 | 1274·49 | 45499·293 | 5·9749 | 3·2927 |
| 35·8 | 112·47 | 1006·60 | 1281·64 | 45882·712 | 5·9833 | 3·2958 |
| 35·9 | 112·78 | 1012·23 | 1288·81 | 46268·279 | 5·9916 | 3·2989 |
| 36·0 | 113·10 | 1017·88 | 1296·00 | 46656·000 | 6·0000 | 3·3019 |
| 36·1 | 113·41 | 1023·54 | 1303·21 | 47045·881 | 6·0083 | 3·3050 |
| 36·2 | 113·73 | 1029·22 | 1310·44 | 47437·928 | 6·0166 | 3·3080 |
| 36·3 | 114·04 | 1034·91 | 1317·69 | 47832·147 | 6·0249 | 3·3111 |
| 36·4 | 114·35 | 1040·62 | 1324·96 | 48228·544 | 6·0332 | 3·3141 |
| 36·5 | 114·67 | 1046·35 | 1332·25 | 48627·125 | 6·0415 | 3·3171 |
| 36·6 | 114·98 | 1052·09 | 1339·56 | 49017·896 | 6·0497 | 3·3202 |
| 36·7 | 115·30 | 1057·84 | 1346·89 | 49430·863 | 6·0580 | 3·3232 |
| 36·8 | 115·61 | 1063·62 | 1354·24 | 49836·032 | 6·0663 | 3·3262 |
| 36·9 | 115·92 | 1069·41 | 1361·61 | 50243·409 | 6·0745 | 3·3292 |
| 37·0 | 116·24 | 1075·21 | 1369·00 | 50653·000 | 6·0827 | 3·3322 |
| 37·1 | 116·55 | 1081·03 | 1376·41 | 51064·811 | 6·0909 | 3·3352 |
| 37·2 | 116·87 | 1086·87 | 1383·84 | 51478·848 | 6·0991 | 3·3382 |
| 37·3 | 117·18 | 1092·72 | 1391·29 | 51895·117 | 6·1073 | 3·3412 |
| 37·4 | 117·50 | 1098·58 | 1398·76 | 52313·624 | 6·1155 | 3·3442 |
| 37·5 | 117·81 | 1104·47 | 1406·25 | 52734·375 | 6·1237 | 3·3472 |
| 37·6 | 118·12 | 1110·36 | 1413·76 | 53157·376 | 6·1318 | 3·3501 |
| 37·7 | 118·44 | 1116·28 | 1421·29 | 53582·633 | 6·1400 | 3·3531 |
| 37·8 | 118·75 | 1122·21 | 1428·84 | 54010·152 | 6·1481 | 3·3561 |
| 37·9 | 119·07 | 1128·15 | 1436·41 | 54439·939 | 6·1563 | 3·3590 |
| 38·0 | 119·38 | 1134·11 | 1444·00 | 54872·000 | 6·1644 | 3·3620 |
| 38·1 | 119·69 | 1140·09 | 1451·61 | 55306·341 | 6·1725 | 3·3649 |
| 38·2 | 120·01 | 1146·08 | 1459·24 | 55742·968 | 6·1806 | 3·3679 |
| 38·3 | 120·32 | 1152·09 | 1466·89 | 56181·887 | 6·1887 | 3·3708 |
| 38·4 | 120·64 | 1158·12 | 1474·56 | 56623·104 | 6·1967 | 3·3737 |

TABLE 21—*Continued.*

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|---------|-----------|------------|---------------|
| 38.5 | 120.95 | 1164.16 | 1482.25 | 57066.625 | 6.2048 | 3.3767 |
| 38.6 | 121.27 | 1170.21 | 1489.96 | 57512.456 | 6.2129 | 3.3797 |
| 38.7 | 121.58 | 1176.28 | 1497.69 | 57960.603 | 6.2209 | 3.3825 |
| 38.8 | 121.80 | 1182.37 | 1505.44 | 58411.072 | 6.2289 | 3.3854 |
| 38.9 | 122.21 | 1188.47 | 1513.21 | 58863.869 | 6.2370 | 3.3883 |
| 39.0 | 122.52 | 1194.59 | 1521.00 | 59319.000 | 6.2450 | 3.3912 |
| 39.1 | 122.84 | 1200.72 | 1528.81 | 59776.471 | 6.2530 | 3.3941 |
| 39.2 | 123.15 | 1206.87 | 1536.64 | 60236.288 | 6.2610 | 3.3970 |
| 39.3 | 123.46 | 1213.04 | 1544.49 | 60698.457 | 6.2689 | 3.3999 |
| 39.4 | 123.78 | 1219.22 | 1552.36 | 61162.984 | 6.2769 | 3.4028 |
| 39.5 | 124.09 | 1225.42 | 1560.25 | 61629.875 | 6.2849 | 3.4056 |
| 39.6 | 124.41 | 1231.63 | 1568.16 | 62099.136 | 6.2928 | 3.4085 |
| 39.7 | 124.72 | 1237.86 | 1576.09 | 62570.773 | 6.3008 | 3.4114 |
| 39.8 | 125.04 | 1244.10 | 1584.04 | 63044.792 | 6.3087 | 3.4142 |
| 39.9 | 125.35 | 1250.36 | 1592.01 | 63521.199 | 6.3166 | 3.4171 |
| 40.0 | 125.66 | 1256.64 | 1600.00 | 64000.000 | 6.3245 | 3.4200 |
| 40.1 | 125.98 | 1262.93 | 1608.01 | 64481.201 | 6.3325 | 3.4228 |
| 40.2 | 126.29 | 1269.23 | 1616.04 | 64964.808 | 6.3404 | 3.4256 |
| 40.3 | 126.61 | 1275.56 | 1624.09 | 65450.827 | 6.3482 | 3.4285 |
| 40.4 | 126.92 | 1281.90 | 1632.16 | 65939.264 | 6.3561 | 3.4313 |
| 40.5 | 127.23 | 1288.25 | 1640.25 | 66430.126 | 6.3639 | 3.4341 |
| 40.6 | 127.55 | 1294.62 | 1648.36 | 66923.416 | 6.3718 | 3.4370 |
| 40.7 | 127.86 | 1301.00 | 1656.49 | 67419.143 | 6.3796 | 3.4398 |
| 40.8 | 128.18 | 1307.41 | 1664.64 | 67917.312 | 6.3875 | 3.4426 |
| 40.9 | 128.49 | 1313.82 | 1672.81 | 68417.929 | 6.3953 | 3.4454 |
| 41.0 | 128.81 | 1320.25 | 1681.00 | 68921.000 | 6.4031 | 3.4482 |
| 41.1 | 129.12 | 1326.70 | 1689.21 | 69426.531 | 6.4109 | 3.4510 |
| 41.2 | 129.43 | 1333.17 | 1697.44 | 69934.528 | 6.4187 | 3.4538 |
| 41.3 | 129.75 | 1339.65 | 1705.69 | 70444.997 | 6.4265 | 3.4566 |
| 41.4 | 130.06 | 1346.14 | 1713.96 | 70957.944 | 6.4343 | 3.4594 |
| 41.5 | 130.38 | 1352.65 | 1722.25 | 71473.375 | 6.4421 | 3.4622 |
| 41.6 | 130.69 | 1359.18 | 1730.56 | 71991.296 | 6.4498 | 3.4650 |
| 41.7 | 131.00 | 1365.72 | 1738.89 | 72511.719 | 6.4575 | 3.4677 |
| 41.8 | 131.32 | 1372.28 | 1747.24 | 73034.632 | 6.4653 | 3.4705 |
| 41.9 | 131.63 | 1378.85 | 1755.61 | 73560.059 | 6.4730 | 3.4733 |
| 42.0 | 131.95 | 1385.44 | 1764.00 | 74088.000 | 6.4807 | 3.4760 |
| 42.1 | 132.26 | 1392.05 | 1772.41 | 74618.461 | 6.4884 | 3.4788 |
| 42.2 | 132.58 | 1398.67 | 1780.84 | 75151.448 | 6.4961 | 3.4815 |

TABLE 21—Continued.

| n | πn ○ | $\pi \frac{n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|---------|-----------|------------|---------------|
| 42·3 | 132·89 | 1405·31 | 1789·29 | 75686·967 | 6·5038 | 3·4843 |
| 42·4 | 133·20 | 1411·96 | 1797·76 | 76225·024 | 6·5115 | 3·4870 |
| 42·5 | 133·52 | 1418·63 | 1806·25 | 76765·625 | 6·5192 | 3·4898 |
| 42·6 | 133·83 | 1425·31 | 1814·76 | 77308·776 | 6·5268 | 3·4925 |
| 42·7 | 134·15 | 1432·01 | 1823·29 | 77854·483 | 6·5345 | 3·4952 |
| 42·8 | 134·46 | 1438·72 | 1831·84 | 78402·752 | 6·5422 | 3·4980 |
| 42·9 | 134·77 | 1445·45 | 1840·41 | 78953·589 | 6·5498 | 3·5007 |
| 43·0 | 135·09 | 1452·20 | 1849·00 | 79507·000 | 6·5574 | 3·5034 |
| 43·1 | 135·40 | 1458·96 | 1857·61 | 80062·991 | 6·5651 | 3·5061 |
| 43·2 | 135·72 | 1465·74 | 1866·24 | 80621·568 | 6·5727 | 3·5088 |
| 43·3 | 136·03 | 1472·54 | 1874·89 | 81182·737 | 6·5803 | 3·5115 |
| 43·4 | 136·35 | 1479·34 | 1883·56 | 81746·504 | 6·5879 | 3·5142 |
| 43·5 | 136·66 | 1486·17 | 1892·25 | 82312·875 | 6·5954 | 3·5169 |
| 43·6 | 136·97 | 1493·01 | 1900·96 | 82881·856 | 6·6030 | 3·5196 |
| 43·7 | 137·29 | 1499·87 | 1909·69 | 83453·453 | 6·6106 | 3·5223 |
| 43·8 | 137·60 | 1506·74 | 1918·44 | 84027·672 | 6·6182 | 3·5250 |
| 43·9 | 137·92 | 1513·63 | 1927·21 | 84604·519 | 6·6257 | 3·5277 |
| 44·0 | 138·23 | 1520·53 | 1936·00 | 85184·000 | 6·6333 | 3·5303 |
| 44·1 | 138·54 | 1527·45 | 1944·81 | 85766·121 | 6·6408 | 3·5330 |
| 44·2 | 138·86 | 1534·39 | 1953·64 | 86350·888 | 6·6483 | 3·5357 |
| 44·3 | 139·17 | 1541·34 | 1962·49 | 86938·307 | 6·6558 | 3·5384 |
| 44·4 | 139·49 | 1548·30 | 1971·36 | 87528·384 | 6·6633 | 3·5410 |
| 44·5 | 139·80 | 1555·28 | 1980·25 | 88121·125 | 6·6708 | 3·5437 |
| 44·6 | 140·12 | 1562·28 | 1989·16 | 88716·536 | 6·6783 | 3·5463 |
| 44·7 | 140·43 | 1569·30 | 1998·09 | 89314·623 | 6·6858 | 3·5490 |
| 44·8 | 140·74 | 1576·33 | 2007·04 | 89915·392 | 6·6933 | 3·5516 |
| 44·9 | 141·06 | 1583·37 | 2016·01 | 90518·849 | 6·7007 | 3·5543 |
| 45·0 | 141·37 | 1590·43 | 2025·00 | 91125·000 | 6·7082 | 3·5569 |
| 45·1 | 141·69 | 1597·51 | 2034·01 | 91733·851 | 6·7156 | 3·5595 |
| 45·2 | 142·00 | 1604·60 | 2043·04 | 92345·408 | 6·7231 | 3·5621 |
| 45·3 | 142·31 | 1611·71 | 2052·09 | 92959·677 | 6·7305 | 3·5648 |
| 45·4 | 142·63 | 1618·83 | 2061·16 | 93576·664 | 6·7379 | 3·5674 |
| 45·5 | 142·94 | 1625·97 | 2070·25 | 94196·375 | 6·7454 | 3·5700 |
| 45·6 | 143·26 | 1633·13 | 2079·36 | 94818·816 | 6·7528 | 3·5726 |
| 45·7 | 143·57 | 1640·30 | 2088·49 | 95443·993 | 6·7602 | 3·5752 |
| 45·8 | 143·88 | 1647·48 | 2097·64 | 96071·912 | 6·7676 | 3·5778 |
| 45·9 | 144·20 | 1654·68 | 2106·81 | 96702·579 | 6·7749 | 3·5805 |

TABLE 21—Continued.

| n | πn ○ | $\frac{\pi n^3}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|---------|------------|------------|---------------|
| 46.0 | 144.51 | 1661.90 | 2116.00 | 97336.000 | 6.7823 | 3.5830 |
| 46.1 | 144.83 | 1669.14 | 2125.21 | 97972.181 | 6.7897 | 3.5856 |
| 46.2 | 145.14 | 1676.39 | 2134.44 | 98611.128 | 6.7971 | 3.5882 |
| 46.3 | 145.46 | 1683.65 | 2143.69 | 99252.847 | 6.8044 | 3.5908 |
| 46.4 | 145.77 | 1690.93 | 2152.96 | 99897.344 | 6.8117 | 3.5934 |
| 46.5 | 146.08 | 1698.23 | 2162.25 | 100544.625 | 6.8191 | 3.5960 |
| 46.6 | 146.40 | 1705.54 | 2171.56 | 101194.696 | 6.8264 | 3.5986 |
| 46.7 | 146.71 | 1712.87 | 2180.89 | 101847.563 | 6.8337 | 3.6011 |
| 46.8 | 147.03 | 1720.21 | 2190.24 | 102503.232 | 6.8410 | 3.6037 |
| 46.9 | 147.34 | 1727.57 | 2199.61 | 103161.709 | 6.8484 | 3.6063 |
| 47.0 | 147.65 | 1734.94 | 2209.00 | 103823.000 | 6.8556 | 3.6088 |
| 47.1 | 147.97 | 1742.34 | 2218.41 | 104487.111 | 6.8629 | 3.6114 |
| 47.2 | 148.28 | 1749.74 | 2227.84 | 105154.048 | 6.8702 | 3.6139 |
| 47.3 | 148.60 | 1757.16 | 2237.29 | 105823.817 | 6.8775 | 3.6165 |
| 47.4 | 148.91 | 1764.60 | 2246.76 | 106496.424 | 6.8847 | 3.6190 |
| 47.5 | 149.23 | 1772.05 | 2256.25 | 107171.875 | 6.8920 | 3.6216 |
| 47.6 | 149.54 | 1779.52 | 2265.76 | 107850.176 | 6.8993 | 3.6241 |
| 47.7 | 149.85 | 1787.01 | 2275.29 | 108531.333 | 6.9065 | 3.6267 |
| 47.8 | 150.17 | 1794.51 | 2284.84 | 109215.352 | 6.9137 | 3.6292 |
| 47.9 | 150.48 | 1802.03 | 2294.41 | 109902.239 | 6.9209 | 3.6317 |
| 48.0 | 150.80 | 1809.56 | 2304.00 | 110592.000 | 6.9282 | 3.6342 |
| 48.1 | 151.11 | 1817.11 | 2313.61 | 111284.641 | 6.9354 | 3.6368 |
| 48.2 | 151.42 | 1824.67 | 2323.24 | 111980.168 | 6.9426 | 3.6393 |
| 48.3 | 151.74 | 1832.25 | 2332.89 | 112678.587 | 6.9498 | 3.6418 |
| 48.4 | 152.05 | 1839.84 | 2342.56 | 113379.904 | 6.9570 | 3.6443 |
| 48.5 | 152.37 | 1847.45 | 2352.25 | 114084.125 | 6.9642 | 3.6468 |
| 48.6 | 152.68 | 1855.08 | 2361.96 | 114791.256 | 6.9714 | 3.6493 |
| 48.7 | 153.00 | 1862.72 | 2371.69 | 115501.303 | 6.9785 | 3.6518 |
| 48.8 | 153.31 | 1870.38 | 2381.44 | 116214.272 | 6.9857 | 3.6543 |
| 48.9 | 153.62 | 1878.05 | 2391.21 | 116930.169 | 6.9928 | 3.6568 |
| 49.0 | 153.94 | 1885.74 | 2401.00 | 117649.000 | 7.0000 | 3.6593 |
| 49.1 | 154.25 | 1893.45 | 2410.81 | 118370.771 | 7.0071 | 3.6618 |
| 49.2 | 154.57 | 1901.17 | 2420.64 | 119095.488 | 7.0143 | 3.6643 |
| 49.3 | 154.88 | 1908.90 | 2430.49 | 119823.157 | 7.0214 | 3.6668 |
| 49.4 | 155.19 | 1916.65 | 2440.36 | 120553.784 | 7.0285 | 3.6692 |
| 49.5 | 155.51 | 1924.42 | 2450.25 | 121287.375 | 7.0356 | 3.6717 |
| 49.6 | 155.82 | 1932.21 | 2460.16 | 122023.936 | 7.0427 | 3.6742 |
| 49.7 | 156.14 | 1940.00 | 2470.09 | 122763.473 | 7.0498 | 3.6767 |

TABLE 21—*Continued.*

| n | πn ○ | $\frac{\pi n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|------|--------------|--------------------------|---------|------------|------------|---------------|
| 49·8 | 156·45 | 1947·82 | 2480·01 | 123505·992 | 7·0569 | 3·6791 |
| 49·9 | 156·77 | 1955·65 | 2490·01 | 124251·499 | 7·0640 | 3·6816 |
| 50·0 | 157·08 | 1963·50 | 2500·00 | 125000·000 | 7·0711 | 3·6840 |
| 51·0 | 160·22 | 2042·82 | 2601·00 | 132651·000 | 7·1414 | 3·7084 |
| 52·0 | 163·36 | 2123·72 | 2704·00 | 140608·000 | 7·2111 | 3·7325 |
| 53·0 | 166·50 | 2206·19 | 2809·00 | 148877·000 | 7·2801 | 3·7563 |
| 54·0 | 169·64 | 2290·22 | 2916·00 | 157464·000 | 7·3485 | 3·7798 |
| 55·0 | 172·78 | 2375·83 | 3025·00 | 166375·000 | 7·4162 | 3·8030 |
| 56·0 | 175·93 | 2463·01 | 3136·00 | 175616·000 | 7·4833 | 3·8259 |
| 57·0 | 179·07 | 2551·76 | 3249·00 | 185193·000 | 7·5498 | 3·8485 |
| 58·0 | 182·21 | 2642·08 | 3364·00 | 195112·000 | 7·6158 | 3·8709 |
| 59·0 | 185·35 | 2733·97 | 3481·00 | 205379·000 | 7·6811 | 3·8980 |
| 60·0 | 188·49 | 2827·44 | 3600·00 | 216000·000 | 7·7460 | 3·9149 |
| 61·0 | 191·63 | 2922·47 | 3721·00 | 226981·000 | 7·8102 | 3·9365 |
| 62·0 | 194·77 | 3019·07 | 3844·00 | 238328·000 | 7·8740 | 3·9579 |
| 63·0 | 197·92 | 3117·25 | 3969·00 | 250047·000 | 7·9373 | 3·9791 |
| 64·0 | 201·06 | 3216·99 | 4096·00 | 262144·000 | 8·0000 | 4·0000 |
| 65·0 | 204·20 | 3318·31 | 4225·00 | 274625·000 | 8·0623 | 4·0207 |
| 66·0 | 207·34 | 3421·20 | 4356·00 | 287496·000 | 8·1240 | 4·0412 |
| 67·0 | 210·48 | 3525·66 | 4489·00 | 300763·000 | 8·1854 | 4·0615 |
| 68·0 | 213·63 | 3631·69 | 4624·00 | 314432·000 | 8·2462 | 4·0817 |
| 69·0 | 216·77 | 3739·29 | 4761·00 | 328509·000 | 8·3066 | 4·1016 |
| 70·0 | 219·91 | 3848·46 | 4900·00 | 343000·000 | 8·3666 | 4·1213 |
| 71·0 | 223·05 | 3959·20 | 5041·00 | 357911·000 | 8·4261 | 4·1408 |
| 72·0 | 226·19 | 4071·51 | 5184·00 | 373248·000 | 8·4853 | 4·1602 |
| 73·0 | 229·33 | 4185·39 | 5329·00 | 389017·000 | 8·5440 | 4·1793 |
| 74·0 | 232·47 | 4300·85 | 5476·00 | 405224·000 | 8·6023 | 4·1983 |
| 75·0 | 235·62 | 4417·87 | 5625·00 | 421875·000 | 8·6603 | 4·2172 |
| 76·0 | 238·76 | 4536·47 | 5776·00 | 438976·000 | 8·7178 | 4·2358 |
| 77·0 | 241·90 | 4656·83 | 5929·00 | 456533·000 | 8·7750 | 4·2543 |
| 78·0 | 245·04 | 4778·37 | 6084·00 | 474552·000 | 8·8318 | 4·2727 |
| 79·0 | 248·18 | 4901·68 | 6241·00 | 493039·000 | 8·8882 | 4·2908 |
| 80·0 | 251·32 | 5026·56 | 6400·00 | 512000·000 | 8·9443 | 4·3089 |
| 81·0 | 254·47 | 5153·01 | 6561·00 | 531441·000 | 9·0000 | 4·3267 |
| 82·0 | 257·61 | 5281·03 | 6724·00 | 551368·000 | 9·0554 | 4·3445 |
| 83·0 | 260·75 | 5410·62 | 6889·00 | 571787·000 | 9·1104 | 4·3621 |
| 84·0 | 263·89 | 5541·78 | 7056·00 | 592704·000 | 9·1652 | 4·3795 |

TABLE 21—Continued.

| n | πn ○ | $\frac{\pi n^2}{4}$ ● | n^2 | n^3 | \sqrt{n} | $\sqrt[3]{n}$ |
|-------|--------------|--------------------------|----------|-------------|------------|---------------|
| 85.0 | 267.03 | 5674.50 | 7225.00 | 614125.000 | 9.2195 | 4.3968 |
| 86.0 | 270.17 | 5808.81 | 7396.00 | 636056.000 | 9.2736 | 4.4140 |
| 87.0 | 273.32 | 5944.69 | 7569.00 | 658503.000 | 9.3274 | 4.4310 |
| 88.0 | 276.46 | 6082.13 | 7744.00 | 681472.000 | 9.3808 | 4.4480 |
| 89.0 | 279.60 | 6221.13 | 7921.00 | 704969.000 | 9.4330 | 4.4647 |
| 90.0 | 282.74 | 6361.74 | 8100.00 | 729000.000 | 9.4868 | 4.4814 |
| 91.0 | 285.88 | 6503.89 | 8281.00 | 753571.000 | 9.5394 | 4.4979 |
| 92.0 | 289.02 | 6647.62 | 8464.00 | 778688.000 | 9.5917 | 4.5144 |
| 93.0 | 292.17 | 6792.92 | 8649.00 | 804357.000 | 9.6437 | 4.5307 |
| 94.0 | 295.31 | 6939.78 | 8836.00 | 830584.000 | 9.6954 | 4.5468 |
| 95.0 | 298.45 | 7088.23 | 9025.00 | 857375.000 | 9.7468 | 4.5629 |
| 96.0 | 301.59 | 7238.24 | 9216.00 | 884736.000 | 9.7980 | 4.5789 |
| 97.0 | 304.73 | 7389.83 | 9409.00 | 912673.000 | 9.8489 | 4.5947 |
| 98.0 | 307.87 | 7542.98 | 9604.00 | 941192.000 | 9.8995 | 4.6104 |
| 99.0 | 311.02 | 7697.68 | 9801.00 | 970299.000 | 9.9499 | 4.6261 |
| 100.0 | 314.16 | 7854.00 | 10000.00 | 1000000.000 | 10.0000 | 4.6416 |

$$\text{Approximately } \sqrt{a^2 \pm b} = a \pm \frac{b}{2a} \quad \text{and} \quad \sqrt[3]{a^3 \pm b} = a \pm \frac{b}{3a^2}$$

TABLE 22.—FORMULÆ FOR MENSURATION OF AREAS AND SOLID CONTENTS.

1.—Triangle.

$$\text{Area} = \frac{1}{2} \times \text{base} \times \text{height.}$$

If all the sides, a , b , c , are known and half their sum is represented by s , so that $s = \frac{a+b+c}{2}$ then

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

2.—Circle.

Area of circle, if d =diameter, r =radius, and $\pi=3.14159$

$$A = \frac{\pi}{4} d^2 = r^2 \pi \quad \dots \quad \left(\frac{\pi}{4} = 0.7854 \right)$$

$$d = 1.12838 \sqrt{A}$$

TABLE 22—Continued.

Area of segment of circle of an arc of a°

$$A = \left(\frac{a}{180} \pi - \sin a \right) \frac{r^2}{2}$$

Or, if d is the diameter and h the height of segment, calculate $\frac{h}{d}$ and find the value x , in the following table, corresponding to $\frac{h}{d}$; the square of the diameter multiplied by x , gives the area of the segment.

$$\text{Area of segment} = x d^2.$$

| $\frac{h}{d}$ | x | $\frac{h}{d}$ | x | $\frac{h}{d}$ | x | $\frac{h}{d}$ | x |
|---------------|--------|---------------|--------|---------------|--------|---------------|--------|
| ·01 | ·00133 | ·14 | ·06683 | ·27 | ·17109 | ·40 | ·29337 |
| ·02 | ·00375 | ·15 | ·07387 | ·28 | ·18002 | ·41 | ·30319 |
| ·03 | ·00687 | ·16 | ·08111 | ·29 | ·18905 | ·42 | ·31304 |
| ·04 | ·01054 | ·17 | ·08854 | ·30 | ·19817 | ·43 | ·32293 |
| ·05 | ·01468 | ·18 | ·09613 | ·31 | ·20737 | ·44 | ·33284 |
| ·06 | ·01924 | ·19 | ·10390 | ·32 | ·21667 | ·45 | ·34278 |
| ·07 | ·02417 | ·20 | ·11182 | ·33 | ·22603 | ·46 | ·35274 |
| ·08 | ·02944 | ·21 | ·11990 | ·34 | ·23547 | ·47 | ·36272 |
| ·09 | ·03501 | ·22 | ·12811 | ·35 | ·24498 | ·48 | ·37270 |
| ·10 | ·04087 | ·23 | ·13646 | ·36 | ·25455 | ·49 | ·38270 |
| ·11 | ·04701 | ·24 | ·14495 | ·37 | ·26418 | ·50 | ·39270 |
| ·12 | ·05338 | ·25 | ·15355 | ·38 | ·27386 | | |
| ·13 | ·06000 | ·26 | ·16226 | ·39 | ·28359 | | |

3.—Cone and Pyramid.

Solid content : $S = \frac{1}{3} \text{ base} \times \text{height}.$

Area of convex surface of right cone : When s = side of cone $= \sqrt{r^2 + h^2}$, where r = radius of base and h = height of cone, the area of convex surface will be

$$A = \pi r s.$$

TABLE 22—*Continued.*

4.—Cylinder.

Area of convex surface $A = 2\pi rh$.Content of cylinder $S = \text{base} \times \text{height}$.

5.—Sphere.

Convex surface $A = 4\pi r^2 = 12.56636r^2$.Surface of segment $A = 2\pi rh$, h = height of segment.Solid content of sphere $S = \frac{4}{3}\pi r^3 = 4.1888r^3$.Solid content of sphere $S = \frac{1}{6}\pi d^3 = 0.5236d^3$.Radius $r = 0.62035 \sqrt[3]{\text{content}}$.

Content of segment of sphere: If a is the radius of the sectional area, h the height of the segment, and r the radius of the sphere,

$$S = \frac{1}{6}\pi h(3a^2 + h^2)$$

$$= \frac{1}{3}\pi h^2(3r - h).$$

Solid content of spherical zone: If a and b are the respective radii of the two terminal surfaces, and h the height,

$$S = \frac{1}{6}\pi h(3a^2 + 3b^2 + h^2).$$

TABLE 23.—HIGH TEMPERATURES, AS MEASURED WITH LE CHATELIER'S PYROMETER.

(Where no other observer is quoted, according to Le Chatelier's publications 1892, 1895, and 1900.)

| | °C. | | °C. |
|--|-------------|--|-----------|
| Spirit lamp (Heraeus), about | 800 | Blast-furnace (grey Bessemer pig) at tuyeres | 1930 |
| Petroleum flame, about | 1500 | iron, on tapping | 1400-1520 |
| Bunsen burner (Lewes)— | | Glass furnaces—pot furnace | 1375 |
| | | temp. of pot during refining | 1310 |
| Top of inner cone | Green cone. | temp. of pot during hot firing | 1045 |
| Middle of outer cone | 1096 | cistern furnace. | 1400 |
| Top | 1533 | cistern furnace, temp. of glass | 1310 |
| Margin | 1175 | Porcelain furnace, for hard porcelain (final temperature). | 1400 |
| (At the level of the top of the inner cone.) | 1333 | Coal-gas, Siemen furnaces, top | 1190 |
| Fusing point of white Swedish pig iron | 1135 | bottom | 1045 |
| grey foundry pig iron | 1220 | retorts (final temperature) | 975 |
| ingot iron, with 3.1 per cent. C. | 1475 | fire gases at chimney | 680 |
| ingot, half hard, 0.3 per cent. C. | 1455 | Annular brick kiln | 1100 |
| ingot steel, 0.9 per cent. C. | 1410 | Electric incandescent lamps | 1800-2100 |
| silver | 962 | light arc (absolute temp.) | 4100 |
| gold | 1065 | Fusing point of fireclay | 1670-1700 |
| copper | 1076 | Segor cone, No. 36 (Heraeus) | 1705 |
| nickel | 1496 | No. 35 | 1685 |
| platinum | 1753 | No. 34 | 1670 |
| Bessemer converter | 1580-1640 | No. 33 | 1650 |
| Siemens-Martin furnace | 1420-1550 | No. 32 | 1635 |
| Siemens crucible steel furnace | 1600 | No. 31 | 1618 |
| Revolving puddling furnace (final temperature) | 1330 | No. 30 | 1605 |

TABLE 24.—SYMBOLS, MOLECULAR WEIGHTS, AND PERCENTAGE COMPOSITION.

Of Compounds which are of importance in the Inorganic Chemical Industries and in Technical Analysis.

Notes.—The salts are arranged alphabetically according to their cations. The H_2O given in the percentage composition includes the water formed by the decomposition of hydrates and of the ammonium-ion.

| Compounds. | Formula. | Molec. weight. O = 16. | Percentage Composition. |
|-----------------------------|---|---------------------------|---|
| Aluminium chloride | $AlCl_3$ | 133.48 | Al 20.30; Cl 79.70. |
| hydroxide | $Al(OH)_3$ | 78.12 | Al_2O_3 65.41; H_2O 34.59. |
| oxide (alumina) | Al_2O_3 | 102.20 | Al 53.03; O 46.97. |
| sulphate | $Al_2(SO_4)_3$ | 342.38 | Al_2O_3 29.85; SO_3 70.15. |
| cryst. | $Al_2(SO_4)_3 \cdot 18H_2O$ | 666.67 | Al_2O_3 15.33; SO_3 36.02; H_2O 48.64. |
| Ammonia | NH_3 | 17.03 | N 82.25; H 17.75. |
| alum | $Al(NH_4)(SO_4)_2 \cdot 12H_2O$ | 453.45 | Al_2O_3 11.27; NH_3 3.76; SO_3 35.31; H_2O 49.66. |
| carbonate | $(NH_4)HCO_3 + (NH_4)CO_2 + (NH_4)_2CO_3$ | 137.11 | NH_3 32.52; CO_2 56.01; H_2O 11.47. |
| chloride | NH_4Cl | 53.50 | NH_3 31.83; HCl 68.17. |
| magnesium arsenate | $(NH_4)_2MgAsO_4 + \frac{1}{2}H_2O$ | 190.33 | MgO 21.18; As_2O_3 60.40; NH_3 8.95; H_2O 9.47. |
| magnesium phosphate, cryst. | $(NH_4)_2MgPO_4 + 6H_2O$ | 245.50 | MgO 16.42; NH_3 6.94; P_2O_5 28.94; H_2O 47.70. |
| Ammonium nitrate | NH_4NO_3 | 80.05 | NH_3 21.28; N_2O_5 67.47; H_2O 11.25. |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O = 16. | Percentage Composition. |
|----------------------------|---|------------------------------|--|
| Ammonium phosphate . . . | $(\text{NH}_4)_2\text{HPO}_4$. . . | 132.13 | NH_3 25.78; P_2O_5 53.77; H_2O 20.45. |
| sodium phosphate . . . | $(\text{NH}_4)\text{HNaPO}_4 + 4\text{H}_2\text{O}$. . . | 209.15 | NH_3 8.14; Na_2O 14.83; P_2O_5 33.96; H_2O 43.07. |
| platinum chloride . . . | $(\text{NH}_4)_2\text{PtCl}_6$. . . | 444.04 | NH_3 7.46; Pt 43.96; Cl 47.91; H_2O 0.47. |
| sulphate . . . | $(\text{NH}_4)_2\text{SO}_4$. . . | 132.14 | NH_3 25.78; SO_3 60.59; H_2O 13.63. |
| thiocyanate . . . | $(\text{NH}_4)\text{CNS}$. . . | 76.11 | NH_3 22.38; H 1.32; CN 34.17; S 42.13. |
| Arsenic pentoxide . . . | As_2O_5 . . . | 229.92 | As 65.21; O 34.79. |
| trioxide . . . | As_2O_3 . . . | 197.92 | As 75.75; O 24.25. |
| trisulphide . . . | As_2S_3 . . . | 246.13 | As 60.91; S 39.09. |
| Barium monoxide . . . | BaO . . . | 153.37 | Ba 89.57; O 10.43. |
| hydroxide . . . | $\text{Ba}(\text{OH})_2$. . . | 171.39 | Ba 89.49; H_2O 10.51. |
| cryst. . . | $\text{Ba}(\text{OH})_2 + 8\text{H}_2\text{O}$. . . | 315.51 | BaO 48.62; H_2O 51.38. |
| carbonate . . . | BaCO_3 . . . | 197.37 | BaO 77.71; CO_2 22.29. |
| chloride . . . | $\text{BaCl}_2 + 2\text{H}_2\text{O}$. . . | 244.32 | BaCl_2 85.25; H_2O 14.75. |
| sulphate . . . | BaSO_4 . . . | 233.43 | BaO 65.70; SO_3 34.30. |
| Calcium oxide (lime) . . . | CaO . . . | 56.07 | Ca 71.46; O 28.54. |
| hydroxide . . . | $\text{Ca}(\text{OH})_2$. . . | 74.09 | CaO 75.68; H_2O 24.32. |
| carbonate . . . | CaCO_3 . . . | 100.07 | CaO 56.03; CO_2 43.97. |
| chlorate . . . | $\text{Ca}(\text{ClO}_3)_2$. . . | 206.99 | CaO 27.09; Cl_2O_7 72.91. |
| chloride . . . | CaCl_2 . . . | 110.99 | Ca 36.10; Cl 63.90. |
| cryst. . . | $\text{CaCl}_2 + 6\text{H}_2\text{O}$. . . | 219.09 | CaCl_2 50.66; H_2O 49.34. |
| hypochlorite . . . | $\text{Ca}(\text{OCl})_2$. . . | 142.99 | CaO 39.21; Cl 49.60; O 11.19. |
| phosphate, primary . . . | $\text{CaH}_2(\text{PO}_4)_2$. . . | 234.18 | CaO 23.94; P_2O_5 60.67; H_2O 15.39. |
| secondary . . . | $\text{CaH}(\text{PO}_4)$. . . | 136.12 | CaO 41.19; P_2O_5 52.19; H_2O 6.62. |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O=16. | Percentage Composition. |
|---|---|----------------------------|--|
| Calcium phosphate, tertiary sulphate (anhydrite) | $\text{Ca}_3(\text{PO}_4)_2$ | 310.29 | CaO 54.21; P_2O_5 45.79. |
| hydrated (gyp- sum) | CaSO_4 | 136.13 | CaO 41.19; SO_3 58.81. |
| sulphide | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ | 172.16 | CaO 32.57; SO_3 46.50; H_2O 20.93. |
| pentasulphide | CaS | 72.13 | Ca 55.55; S 44.45. |
| sulphite. | CaS_2 | 200.37 | Ca 20.00; S 80.00. |
| thiosulphate | CaSO_3 | 120.13 | CaO 46.67; SO_2 53.33. |
| Carbon dioxide | CaS_2O_3 | 152.19 | CaO 36.84; SO_2 42.09; S 21.07. |
| monoxide | CO_2 | 44.00 | C 27.27; O 72.73. |
| Chloric acid | CO | 28.00 | C 42.86; O 57.14. |
| Copper oxide | HClO_2 | 84.47 | Cl 41.98; O 47.36; H_2O 10.66. |
| chloride | CuO | 79.57 | Cu 79.89; O 20.11. |
| sulphide (cuprous) | CuCl_2 | 134.49 | Cu 47.27; O 52.73. |
| sulphate (cupric) | Cu_2S | 159.20 | Cu 79.86; S 20.14. |
| Ethylene | CuS | 95.63 | Cu 66.47; S 33.53. |
| Hydrochloric acid | $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ | 249.71 | CuO 31.37; SO_3 32.06; H_2O 36.07. |
| Hypochlorous acid | C_2H_4 | 28.03 | C 85.62; H 14.38. |
| anhydride | HCl | 36.47 | Cl 97.24; H 2.76. |
| Iron oxide (ferric) | HOCl | 52.47 | Cl 67.59; O 30.49; H 1.92. |
| hydrated (ferric hydroxide) | Cl_2O | 86.92 | Cl 81.59; O 18.41. |
| Iron chloride (ferrous) cryst. | Fe_2O_3 | 159.68 | Fe 69.94; O 30.06. |
| | $\text{Fe}(\text{OH})_3$ | 106.86 | Fe_2O_3 74.72; H_2O 25.28. |
| | FeCl_2 | 126.76 | Fe 44.05; Cl 55.95. |
| | $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ | 198.82 | FeCl_2 63.75; H_2O 36.25. |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O = 16. | Percentage Composition. |
|--------------------------|---|------------------------------|--|
| Iron chloride (ferric) | FeCl ₃ | 162.22 | Fe 34.42; Cl 65.58. |
| bisulphide (pyrites) | FeS ₂ | 119.96 | Fe 46.55; S 53.45. |
| sulphate (ferrous) | FeSO ₄ ·7H ₂ O | 277.95 | Fe 20.09; O 57.6; SO ₃ 28.80; H ₂ O 45.55. |
| Lead monoxide (litharge) | PbO | 223.20 | Pb 92.83; O 7.17. |
| oxide (red lead) | Pb ₃ O ₄ | 685.60 | Pb 90.67; O 9.33. |
| carbonate | PbCO ₃ | 267.20 | PbO 83.53; CO ₂ 16.47. |
| chloride | PbCl ₂ | 278.12 | Pb 74.50; Cl 25.50. |
| sulphate | PbSO ₄ | 303.26 | PbO 73.60; SO ₃ 26.40. |
| sulphide | PbS | 239.26 | Pb 86.60; S 13.40. |
| Magnesium oxide | MgO | 40.32 | Mg 60.32; O 39.68. |
| hydroxide | Mg(OH) ₂ | 58.34 | MgO 69.12; H ₂ O 30.88. |
| chloride | MgCl ₂ | 95.24 | Mg 25.54; Cl 74.46. |
| cryst. | MgCl ₂ ·6H ₂ O | 203.84 | MgCl ₂ 46.84; H ₂ O 53.16. |
| carbonate | MgCO ₃ | 84.32 | MgO 47.82; CO ₂ 52.18. |
| pyrophosphate | Mg ₂ P ₂ O ₇ | 222.72 | MgO 36.21; P ₂ O ₅ 63.79. |
| sulphate, cryst. | MgSO ₄ ·7H ₂ O | 246.49 | MgO 16.36; SO ₃ 32.48; H ₂ O 51.16. |
| Manganese protoxide. | MnO | 70.93 | Mn 77.44; O 22.56. |
| sesquioxide | Mn ₂ O ₃ | 157.86 | Mn 69.59; O 30.41. |
| dioxide | MnO ₂ | 86.93 | Mn 63.19; O 36.81. |
| Manganous manganic oxide | Mn ₃ O ₄ | 228.79 | Mn 72.03; O 27.97. |
| chloride | MnCl ₂ | 125.85 | Mn 43.65; Cl 56.35. |
| sulphate | MnSO ₄ | 150.99 | MnO 46.98; SO ₃ 53.02. |
| Mercurous chloride | HgCl | 236.06 | Hg 84.98; Cl 15.02. |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O=16. | Percentage Composition. |
|---|---|----------------------------|---|
| Mercuric chloride | HgCl_2 | 271.52 | Hg 73.88; Cl 26.12. |
| Methane | CH_4 | 16.03 | C 74.85; H 25.15. |
| Nitrosulphonic acid (nitrososulphuric acid, chamber crystals) | $\text{SO}_3(\text{OH})(\text{ONO})$ | 127.08 | SO_3 63.00; N_2O_3 29.91; H_2O 7.09. |
| Nitrous oxide | N_2O | 44.02 | N 63.65; O 36.35. |
| Nitric oxide | NO | 30.01 | N 46.68; O 53.32. |
| Nitrous anhydride | N_2O_3 | 76.02 | N 36.86; O 63.14. |
| Nitric acid | NO_2H | 47.02 | N_2O_3 80.84; H_2O 19.16. |
| Nitric peroxide (tetroxide) | NO_2 or N_2O_4 | 62.01 | N 30.45; O 69.55. |
| acid | NO_2H | 92.02 | N_2O_3 85.71; H_2O 14.29. |
| Pentathionic acid, <i>cf.</i> Sulphur. | P_2O_5 | 142.08 | P 43.69; O 56.31. |
| Phosphoric pentoxide | H_3PO_4 | 98.06 | P_2O_5 72.44; H_2O 27.56. |
| acid, ortho- | $\text{H}_4\text{P}_2\text{O}_7$ | 178.11 | P_2O_5 79.77; H_2O 20.23. |
| pyro- | $\text{H}_6\text{P}_3\text{O}_{10}$ | 80.05 | P_2O_5 88.75; H_2O 11.25. |
| meta- | H_2PtCl_6 | 410.00 | Pt 47.61; Cl 51.90; H 0.49. |
| Platinum-hydrogen chloride | K_2O | 94.20 | K 83.01; O 16.99. |
| Potassium oxide. | KOH | 56.11 | K_2O 83.95; H_2O 16.05. |
| hydroxide | K_2CO_3 | 138.20 | K_2O 68.16; CO_2 31.84. |
| carbonate | KHCO_3 | 100.11 | K_2O 47.05; CO_2 43.95; H_2O 9.00. |
| bicarbonate | $\text{K}_2\text{Cr}_2\text{O}_7$ | 294.20 | K_2O 32.02; Cr_2O_3 67.98. |
| dichromate | KClO_3 | 122.56 | K_2O 38.43; Cl 28.93; O 32.64. |
| chlorate | KCl | 74.56 | K 52.44; Cl 47.56. |
| chloride | K_2CrO_4 | 194.20 | K_2O 48.51; CrO_3 51.49. |
| chromate | | | |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O=16. | Percentage Composition. |
|----------------------------|----------------------------------|----------------------------|---|
| Potassium cyanide | KCN | 65.11 | K 60.05; CN 39.95. |
| ferricyanide | $K_3Fe(CN)_6$ | 329.20 | K 35.63; Fe 16.96; CN 47.41. |
| ferrocyanide | $K_4Fe(CN)_6 \cdot 3H_2O$ | 422.35 | K 37.03; Fe 13.22; CN 36.95; H_2O 12.80. |
| iodide | KI. | 166.02 | K 23.55; I 76.45. |
| nitrate | KNO ₃ | 101.11 | K ₂ O 46.58; N ₂ O ₅ 53.42. |
| nitrite | KNO ₂ | 85.11 | K ₂ O 55.31; N ₂ O ₃ 44.66. |
| permanganate | KMnO ₄ | 158.03 | K ₂ O 29.80; Mn ₂ O ₇ 70.20. |
| phosphate | K ₂ HPO ₄ | 174.25 | K ₂ O 54.06; P ₂ O ₅ 40.77; H_2O 5.17. |
| platinum chloride | K ₂ PtCl ₆ | 486.16 | Pt 40.15; Cl 43.76; K 16.09=(KCl 30.67). |
| silicate | K ₂ SiO ₃ | 154.50 | K ₂ O 60.97; SiO ₂ 39.03. |
| sulphate | K ₂ SO ₄ | 174.26 | K ₂ O 54.66; SO ₃ 45.94. |
| bisulphate | KHSO ₄ | 136.17 | K ₂ O 34.59; SO ₃ 58.80; H_2O 6.61. |
| sulphide | K ₂ S | 110.26 | K ₂ O 92; S 29.08. |
| sulphite, cryst. | $K_2SO_3 \cdot 2H_2O$ | 194.29 | K ₂ O 48.48; SO ₂ 32.97; H_2O 18.55. |
| bisulphite | KHSO ₃ | 120.17 | K ₂ O 39.20; SO ₂ 55.80; H_2O 7.50. |
| thiocyanate | KCN.S | 97.17 | K 40.24; CNS 59.76. |
| Potash alum | $KAl(SO_4)_2 \cdot 12H_2O$ | 474.51 | K ₂ O 9.93; Al ₂ O ₃ 10.77; SO ₃ 33.74; H_2O 45.56. |
| Selenious anhydride | SeO ₂ | 111.20 | Se 71.22; O 28.78. |
| Silicic anhydride (silica) | SiO ₂ | 60.30 | Si 46.93; O 53.07. |
| Silver bromide | AgBr | 187.80 | Ag 57.44; Br 42.56. |
| chloride | AgCl | 143.34 | Ag 75.26; Cl 24.74. |
| iodide | AgI | 234.80 | Ag 45.95; I 54.05. |
| nitrate | AgNO ₃ | 169.89 | Ag 63.50; NO ₃ 36.50. |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O = 16. | Percentage Composition. |
|---------------------|--|------------------------------|--|
| Silver sulphide . | Ag_2S . | 247.82 | Ag 87.06; S 12.94. |
| thiocyanate . | AgCNS . | 165.96 | Ag 65.00; CNS 35.00. |
| Sodium oxide . | Na_2O . | 62.00 | Na 74.19; O 25.81. |
| hydroxide . | NaOH . | 40.01 | Na_2O 77.48; H_2O 22.52. |
| aluminate . | Na_3AlO_3 . | 144.10 | Na_2O 64.54; Al_2O_3 35.46. |
| borate . | $\text{Na}_2\text{B}_2\text{O}_7 + 10\text{H}_2\text{O}$. | 164.20 | Na_2O 37.76; Al_2O_3 62.24. |
| carbonate anhydrous | Na_2CO_3 . | 381.96 | Na_2O 16.24; B_2O_3 36.57; H_2O 47.19. |
| decahydrated | $\text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O}$. | 106.00 | Na_2O 53.49; CO_2 41.51. |
| bicarbonate . | NaHCO_3 . | 286.16 | Na_2O 21.67; CO_2 15.38; H_2O 62.95. |
| chlorate . | NaHCO_3 . | 84.01 | Na_2O 36.90; CO_2 52.38; H_2O 10.72. |
| chloride . | NaClO_3 . | 106.46 | Na_2O 29.12; Cl_2O_5 70.88. |
| chromate . | NaCl . | 58.46 | Na_2O 39.34; Cl 60.66. |
| bichromate | Na_2CrO_4 . | 162.00 | Na_2O 38.27; Cr_2O_3 61.73. |
| hypochlorite . | NaHCrO_4 . | 140.01 | Na_2O 22.14; CrO_3 71.42; H_2O 6.44. |
| nitrate . | NaOCl . | 74.46 | Na_2O 41.63; Cl_2O 58.37. |
| nitrite . | NaNO_3 . | 85.01 | Na_2O 36.47; N_2O_5 63.53. |
| phosphate | NaNO_3 . | 69.01 | Na_2O 44.92; N_2O_5 55.08. |
| silicate . | $\text{Na}_2\text{HPO}_4 + 12\text{H}_2\text{O}$. | 358.24 | Na_2O 17.31; P_2O_5 19.83; H_2O 62.86. |
| sulphate . | Na_2SiO_3 . | 122.30 | Na_2O 50.69; SiO_2 49.31. |
| cryst. | Na_2SO_4 . | 142.06 | Na_2O 43.64; SO_3 56.36. |
| bisulphate | $\text{Na}_2\text{SO}_4 + 10\text{H}_2\text{O}$. | 322.22 | Na_2O 19.24; SO_3 24.85; H_2O 55.91. |
| sulphide. | NaHSO_4 . | 120.07 | Na_2O 25.82; SO_3 66.68; H_2O 7.50. |
| hydrogen sulphide. | Na_2S . | 78.06 | Na 53.93; S 41.07. |
| sulphite, cryst. | NaHS . | 56.07 | Na_2S 69.61; H_2S 30.39. |
| | $\text{Na}_2\text{SO}_3 + 7\text{H}_2\text{O}$. | 252.17 | Na_2O 24.59; SO_2 25.40; H_2O 50.01. |

TABLE 24—Continued.

| Compounds. | Formula. | Molec. weight. O = 16. | Percentage Composition. |
|-----------------------------------|---|------------------------------|--|
| Sodium bisulphite thiosulphate | $\cdot \cdot \cdot \text{NaHSO}_3$ $\cdot \cdot \cdot \text{Na}_2\text{S}_2\text{O}_3 + 5\text{H}_2\text{O}$ | 104.07 248.20 | Na_2O 29.79; SO_2 61.56; H_2O 8.65. Na_2O 24.98; S 12.92; SO_2 25.81; H_2O 36.29. |
| Sulphur dioxide | $\cdot \cdot \cdot \text{SO}_2$ | 64.06 | S 50.05; O 49.95. |
| Sulphur trioxide | $\cdot \cdot \cdot \text{SO}_3$ | 80.06 | S 40.04; O 59.96. |
| Sulphuric acid | $\cdot \cdot \cdot \text{H}_2\text{SO}_4$ | 98.08 | SO_3 81.63; H_2O 18.37. |
| pyro- | $\cdot \cdot \cdot \text{H}_2\text{S}_2\text{O}_7$ | 178.14 | H_2SO_4 55.06; SO_3 44.94. |
| Trithionic acid | $\cdot \cdot \cdot \text{H}_2\text{S}_3\text{O}_6$ | 194.20 | SO_3 41.23; SO_2 32.99; S 16.51; H_2O 9.27. |
| Tetrathionic acid | $\cdot \cdot \cdot \text{H}_2\text{S}_4\text{O}_8$ | 226.26 | SO_3 35.38; SO_2 28.31; S 28.34; H_2O 7.97. |
| Pentathionic acid | $\cdot \cdot \cdot \text{H}_2\text{S}_5\text{O}_{10}$ | 258.32 | SO_3 30.99; SO_2 24.80; S 37.23; H_2O 6.98. |
| Sulphuretted hydrogen | $\cdot \cdot \cdot \text{H}_2\text{S}$ | 34.08 | S 94.08; H 5.92. |
| Tin chloride (stannous) | $\cdot \cdot \cdot \text{SnCl}_2 + 2\text{H}_2\text{O}$ | 255.65 | Sn 52.60; Cl 31.43; H_2O 15.97. |
| Water | $\cdot \cdot \cdot \text{H}_2\text{O}$ | 18.02 | H 11.19; O 88.81. |
| Zinc oxide | $\cdot \cdot \cdot \text{ZnO}$ | 81.37 | Zn 80.34; O 19.66. |
| chloride | $\cdot \cdot \cdot \text{ZnCl}_2$ | 135.29 | Zn 47.96; Cl 52.04. |
| sulphate | $\cdot \cdot \cdot \text{ZnSO}_4$ | 161.43 | ZnO 50.41; SO_3 49.59. |
| cryst. | $\cdot \cdot \cdot \text{ZnSO}_4 + 7\text{H}_2\text{O}$ | 287.54 | ZnO 28.30; SO_3 27.84; H_2O 43.86. |
| sulphide | $\cdot \cdot \cdot \text{ZnS}$ | 97.13 | Zn 67.09; S 32.91. |

TABLE 25.—FACTORS FOR CALCULATING GRAVIMETRIC ANALYSES.

| Substance weighed. | Substance to be determined. | Factor. | log |
|---|---|---------|------------|
| Ammonium. | | | |
| Ammonium chloride, NH_4Cl | Ammonia, NH_3 | 0·3184 | 0·50301 -1 |
| Ammonium platinum chloride, $(\text{NH}_4)_2\text{PtCl}_6$ | Ammonia, NH_3 | 0·0767 | 0·88488 -2 |
| | Nitrogen N | 0·0631 | 0·80000 -2 |
| Arsenic. | | | |
| Arsenic trisulphide, As_2S_3 | Arsenic, As | 0·6092 | 0·78475 -1 |
| | Arsenic trioxide, As_2O_3 | 0·8042 | 0·90536 -1 |
| | Arsenic anhydride, As_2O_5 | 0·9342 | 0·97045 -1 |
| Ammonium magnesium arsenate, $\text{Mg}(\text{NH}_4)\text{AsO}_4 + \frac{1}{2} \text{ aq.}$ | Arsenic, As | 0·3939 | 0·59532 -1 |
| | Arsenic trioxide, As_2O_3 | 0·5200 | 0·71595 -1 |
| | Arsenic anhydride, As_2O_5 | 0·6039 | 0·78100 -1 |
| Barium. | | | |
| Barium sulphate, BaSO_4 | Barium oxide, $\left\{ \begin{array}{l} \text{BaO} \\ \text{BaO} \\ \text{BaO} \end{array} \right.$ | 0·6570 | 0·81755 -1 |
| Barium carbonate, BaCO_3 | | 0·7770 | 0·89043 -1 |
| Barium silicofluoride, BaSiF_6 | | 0·5483 | 0·73906 -1 |
| Calcium. | | | |
| Calcium sulphate, CaSO_4 | Calcium oxide, $\left\{ \begin{array}{l} \text{CaO} \\ \text{CaO} \end{array} \right.$ | 0·4119 | 0·61478 -1 |
| Calcium carbonate, CaCO_3 | | 0·5603 | 0·74843 -1 |
| Carbon. | | | |
| Barium carbonate, BaCO_3 | Carbon dioxide, CO_2 | 0·2229 | 0·34817 -1 |
| Calcium carbonate, CaCO_3 | Carbon dioxide, CO_2 | 0·4397 | 0·64315 -1 |
| Carbon dioxide, CO_2 | Carbon, C | 0·2727 | 0·43568 -1 |
| Chlorine. | | | |
| Silver chloride, AgCl | Chlorine, Cl | 0·2474 | 0·39337 -1 |
| | Potassium chloride, KCl | 0·5202 | 0·71614 -1 |
| | Sodium chloride, NaCl | 0·4078 | 0·61049 -1 |
| | Hydrogen chloride, HCl | 0·2544 | 0·40554 -1 |
| | | | |
| Copper. | | | |
| Cupric oxide, CuO | Copper, Cu | 0·7989 | 0·90250 -1 |
| Cuprous sulphide, Cu_2S | Copper, Cu | 0·7986 | 0·90234 -1 |
| | Cupric oxide, CuO | 0·9996 | 0·99984 -1 |
| Hydrogen. | | | |
| Water, H_2O | Hydrogen, H | 0·1119 | 0·04884 -1 |
| Iron. | | | |
| Ferric oxide, Fe_2O_3 | Iron, Fe | 0·6994 | 0·84473 -1 |
| | Ferrous oxide, FeO | 0·8998 | 0·95415 -1 |
| Lead. | | | |
| Lead monoxide, PbO | Lead, Pb | 0·9283 | 0·96770 -1 |
| Lead sulphate, PbSO_4 | Lead, Pb | 0·6833 | 0·83459 -1 |
| | Lead oxide, PbO | 0·7360 | 0·86688 -1 |

FACTORS FOR GRAVIMETRIC ANALYSES 71

TABLE 25—*Continued.*

| Substance weighed. | Substance to be determined. | Factor. | log |
|---|---|---------|-------------|
| Lead. | | | |
| Lead sulphide, PbS | Lead Pb | 0·8660 | 0·93752 - 1 |
| Lead, Pb | Lead oxide, PbO | 0·9329 | 0·96982 - 1 |
| | Lead oxide, PbO | 1·0772 | 0·03230 |
| Magnesium. | | | |
| Magnesium pyrophosphate, $Mg_2P_2O_7$ | Magnesium oxide, MgO | 0·3621 | 0·55881 - 1 |
| Magnesium sulphate, $MgSO_4$ | Magnesium oxide, MgO | 0·3349 | 0·52497 - 1 |
| Manganese. | | | |
| Manganic manganic oxide, Mn_2O_4 | Manganese, Mn | 0·7203 | 0·85749 - 1 |
| | Manganese, Mn | 0·6311 | 0·80034 - 1 |
| Manganese sulphide, MnS | Manganous oxide, MnO | 0·8154 | 0·91136 - 1 |
| Nitrogen. | | | |
| Ammonium platinum chloride, $(NH_4)_2PtCl_6$ | Nitrogen, N | 0·0631 | 0·80003 - 2 |
| Platinum, Pt | Nitrogen, N | 0·1435 | 0·15693 - 1 |
| Phosphorus. | | | |
| Magnesium pyrophosphate, $Mg_2P_2O_7$ | Phosphorus, P | 0·2787 | 0·44521 - 1 |
| | Phosphorus pent-oxide, P_2O_5 | 0·6380 | 0·80479 - 1 |
| Potassium. | | | |
| Potassium chloride, KCl | Potassium oxide, K_2O | 0·6317 | 0·80051 - 1 |
| Potassium chloride | Potassium K | 0·5244 | 0·71967 - 1 |
| Potassium-platinum chloride, K_2PtCl_6 (reduction factors adopted at Stassfurt) | Potassium oxide | 0·1930 | 0·28556 - 1 |
| | Potassium chloride | 0·3056 | 0·48515 - 1 |
| Potassium sulphate | Potassium sulphate | 0·3571 | 0·55279 - 1 |
| Potassium sulphate | Potassium oxide | 0·5106 | 0·73285 - 1 |
| Potassium sulphate | Potassium | 0·4488 | 0·65201 - 1 |
| Sodium. | | | |
| Sodium sulphate, Na_2SO_4 | Sodium oxide, Na_2O | 0·4364 | 0·63992 - 1 |
| Sodium carbonate, Na_2CO_3 | Sodium oxide, Na_2O | 0·5849 | 0·76708 - 1 |
| Sodium chloride, NaCl | Sodium oxide, Na_2O | 0·5303 | 0·72450 - 1 |
| Sulphur. | | | |
| | Sulphur, S | 0·1373 | 0·13780 - 1 |
| | Sulphur dioxide, SO_2 | 0·2744 | 0·43843 - 1 |
| | Sulphur trioxide, SO_3 | 0·3429 | 0·53522 - 1 |
| Barium sulphate, $BaSO_4$ | Sulphuric acid, H_2SO_4 | 0·4202 | 0·62340 - 1 |
| | Sodium sulphate, Na_2SO_4 | 0·6086 | 0·78431 - 1 |
| Zinc. | | | |
| Zinc oxide, ZnO | Zinc, Zn | 0·8034 | 0·90492 - 1 |
| | Zinc, Zn | 0·6709 | 0·82669 - 1 |
| Zinc sulphide, ZnS | Zinc oxide, ZnO | 0·8352 | 0·92177 - 1 |

TABLE 26.—DENSITY OF GASES AND VAPOURS.
And Litre Weights at 0° C., and at a pressure of 760 mm.

gram. mol. of each gas = 22.412 litres. 1 litre of each gas = $0.04462 \times$ its molecular weight. The spec. gravity of gases referred to atmospheric air as unity is = its molecular weight divided by 28.945, or = $34.55 \times$ molec. weight. 1000

| Gas. | Formula. | Molecular weight. | Weight of 1 litre in grams. | | Density, air = 1. | | Observer. |
|-----------------------|----------|-------------------|-----------------------------|-----------|-------------------|-----------|------------------|
| | | | Calculated. | Observed. | Calculated. | Observed. | |
| Acetylene | C_2H_2 | 26.02 | 1.1610 | 1.189 | 0.8989 | 0.9056 | Leduc. |
| Ammonia | NH_3 | 17.03 | 0.7606 | 1.7708 | 0.5883 | 0.5962 | Saussure. |
| Atmospheric air | ... | ... | 1.2928 | ... | 1.0000 | ... | (at 228°) Jahn. |
| Bromine | Br_2 | 159.84 | 7.1388 | 7.1418 | 5.5220 | 5.5243 | Treadwell. |
| Chlorine | Cl_2 | 70.92 | 3.1674 | 3.2191 | 2.4501 | 2.491 | Rayleigh, Leduc. |
| Carbon monoxide. | CO | 28.00 | 1.2505 | 1.2503 | 0.9673 | 0.96716 | Guye. |
| Carbon dioxide. | CO_2 | 44.00 | 1.9651 | 1.9768 | 1.5201 | 1.52908 | Saussure. |
| Ethylene | C_2H_4 | 28.03 | 1.2519 | 1.2737 | 0.9683 | 0.9852 | Morley. |
| Hydrogen | H_2 | 2.02 | 0.0900 | 0.08987 | 0.06965 | 0.06952 | Scheuer. |
| Hydrogen chloride | HCl | 36.47 | 1.6289 | 1.6394 | 1.2598 | 1.2681 | Baume, Perrot. |
| Methane | CH_4 | 16.03 | 0.7159 | 0.7160 | 0.5538 | 0.5545 | Rayleigh, Leduc. |
| Nitrogen | N_2 | 28.02 | 1.2514 | 1.2505 | 0.9680 | 0.96727 | Guye. |
| Nitrous oxide | N_2O | 44.02 | 1.9660 | 1.9777 | 1.5208 | 1.5298 | Guye. |
| Nitric oxide | NO | 30.01 | 1.3403 | 1.3402 | 1.0368 | 1.0367 | Guye. |
| Peroxide | NO_2 | 46.01 | 2.0549 | ... | 1.5895 | ... | ... |
| Oxygen | N_2O_4 | 92.02 | 4.1098 | ... | 3.1790 | ... | Guye. |
| Sulphur | O_2 | 32.00 | 1.4292 | 1.4292 | 1.1055 | 1.1055 | ... |
| Sulphuretted hydrogen | S_2 | 64.12 | 2.8610 | ... | 2.2130 | ... | ... |
| Sulphur dioxide | H_2S | 34.09 | 1.5226 | 1.5392 | 1.1777 | 1.1906 | Baume, Perrot. |
| Sulphur trioxide | SO_2 | 64.07 | 2.8615 | 2.9266 | 2.2134 | 2.2638 | Jaquero, Pintza. |
| Water | SO_3 | 80.06 | 3.5722 | ... | 2.7631 | ... | ... |
| | H_2O | 18.02 | 0.8040 | ... | 0.6219 | ... | ... |

TABLE 27.—CALCULATION OF THE C.C. READ OFF IN GAS-VOLUMETRIC ANALYSIS, TO MILLIGRAMS OF THE SUBSTANCE REQUIRED.

N.B.—The data for this calculation are not the theoretically calculated, but the observed densities of the gases, according to Table 26.

| c.c. at 0° and 760 mm. | 1. | log | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|--|--------|-------------|--------|---------|---------|---------|---------|---------|---------|---------|
| CO ₂ = mg CO ₂ | 1.9768 | 0.29597 | 3.9586 | 5.9304 | 7.9072 | 9.8840 | 11.8608 | 13.8376 | 15.8144 | 17.7912 |
| CO ₂ = mg CaCO ₃ | 4.4968 | 0.65290 | 8.9936 | 13.4904 | 17.9872 | 22.4840 | 26.9808 | 31.4776 | 35.9744 | 40.4712 |
| O = mg O | 1.4292 | 0.15509 | 2.8584 | 4.2876 | 5.7168 | 7.1460 | 8.5752 | 10.0044 | 11.4336 | 12.8628 |
| (O = mg O)* | 0.7146 | 0.85406 - 1 | 1.4292 | 2.1437 | 2.8584 | 3.5730 | 4.2876 | 5.0022 | 5.7168 | 6.4314 |
| O = mg MnO ₂ | 3.8825 | 0.58912 | 7.7650 | 11.6475 | 15.5300 | 19.4125 | 23.2950 | 27.1775 | 31.0600 | 34.9625 |
| O = mg Cl | 3.1675 | 0.50072 | 6.3350 | 9.5025 | 12.6700 | 15.8375 | 19.0050 | 22.1725 | 25.3408 | 28.5085 |
| N = mg N | 1.2505 | 0.09709 | 2.5010 | 3.7515 | 5.0020 | 6.2525 | 7.5030 | 8.7535 | 10.0040 | 11.2545 |
| N = mg NH ₃ | 1.5200 | 0.18184 | 3.0400 | 4.5600 | 6.0800 | 7.6000 | 9.1200 | 10.6400 | 12.1600 | 13.6800 |
| (N = mg N)† | 1.2318 | 0.10782 | 2.5636 | 3.8454 | 5.1272 | 6.4090 | 7.6908 | 8.9726 | 10.2544 | 11.5362 |
| (N = mg N) [†] | 1.5582 | 0.19263 | 3.1164 | 4.6746 | 6.2328 | 7.7910 | 9.3492 | 10.9074 | 12.4656 | 14.0238 |
| NO = mg N | 0.6256 | 0.79633 - 1 | 1.2513 | 1.8769 | 2.5024 | 3.1280 | 3.7536 | 4.3792 | 5.0048 | 5.6304 |
| NO = mg NO | 1.3403 | 0.12720 | 2.6806 | 4.0209 | 5.3612 | 6.7015 | 8.0418 | 9.3821 | 10.7224 | 12.0627 |
| NO = mg N ₂ O | 1.6974 | 0.22979 | 3.3948 | 5.0922 | 6.7896 | 8.4870 | 10.1846 | 11.8818 | 13.5792 | 15.2766 |
| NO = mg HNO ₃ | 2.8143 | 0.44937 | 5.6286 | 8.4429 | 11.2572 | 14.0715 | 16.8858 | 19.7001 | 22.5144 | 25.3297 |
| NO = mg NaNO ₃ | 3.7963 | 0.57936 | 7.5926 | 11.3889 | 15.1852 | 18.9815 | 22.7778 | 26.5741 | 29.3704 | 32.1874 |
| Cl = mg Cl | 3.2191 | 0.50773 | 6.4382 | 9.6573 | 12.8764 | 16.0955 | 19.3146 | 22.5337 | 25.7528 | 28.9719 |
| H ₂ S = mg H ₂ S | 1.5392 | 0.18730 | 3.0784 | 4.6176 | 6.1568 | 7.6960 | 9.2352 | 10.7744 | 12.3136 | 13.8528 |

* In the case of the hydrogen peroxide methods, where only half of the oxygen liberated comes from the substance analysed.

† In the case of the azotometric methods, where the potassium-bromate method yields 2.3 per cent. too little nitrogen.

TABLE 28.—SOLUBILITY OF SALTS AND CERTAIN ELEMENTS.

Note.—The solubility is given in parts of the anhydrous salt dissolved by 100 parts of water, though the actual substance in equilibrium with the solution may be a hydrate.

| 100 parts of Water dissolve | | At 0°. | At 15°. | At 30°. | At 50°. | At 70°. | At 100°. |
|---|--|--------|---------|---------|---------|---------|----------|
| SUBSTANCE. | SOLID PHASE. | | | | | | |
| Alum, ammonia | $\text{Al}(\text{NH}_4)(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ | 2·6 | 5·5 | 9·1 | 15·9 | 27·0 | 109·7 |
| potash | $\text{AlK}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ | 3·0 | 5·0 | 8·4 | 17 | 36 | 154 |
| Aluminium sulphate. | $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ | 31·3 | 34·9 | 40·4 | 52·1 | 66·2 | 89·1 |
| Ammonium bicarbonate | NH_4HCO_3 | 11·9 | 17·3 | 27 | ... | ... | ... |
| bromide. | NH_4Br | ... | 70 | 81 | 94 | ... | ... |
| chloride. | NH_4Cl | 29·7 | 35·3 | 41·4 | 50·4 | 60·2 | 77·3 |
| nitrate. | NH_4NO_3 | 118 | 162 | 242 | 344 | 499 | 871 |
| Barium chloride | $(\text{NH}_4)_2\text{SO}_4$ | 70·6 | 74·2 | 78·0 | 84·4 | 91·6 | 103·3 |
| hydroxide (wt. of BaO) | $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ | 31·6 | 34·5 | 38·2 | 43·6 | 49·4 | 58·8 |
| nitrate. | $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ | 1·5 | 2·85 | 5·0 | 11·7 | 31·9 | ... |
| Boric acid (wt. of B_2O_3) | $\text{Ba}(\text{NO}_3)_2$ | 5·0 | 8·1 | 11·6 | 17·1 | 23·6 | 34·2 |
| Bromine | $\text{B}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ | 1·1 | 1·9 | 3·1 | 5·1 | 8·0 | 15·7 |
| Bromine | $\text{Br}_2 \cdot 10\text{H}_2\text{O}$ (up to 6·2°) | 2·37 | ... | 3·44 | 3·52 | ... | ... |
| Calcium carbonate | CaCO_3 | ... | 0·0013 | ... | ... | ... | ... |
| chloride | $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ | 59·5 | 68 | 102 | ... | ... | ... |
| hydroxide | $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ | ... | ... | ... | ... | 141·7 | 159·0 |
| nitrate. | $\text{Ca}(\text{OH})_2$ | 0·131 | 0·129 | 0·113 | 0·096 | 0·075 | ... |
| suphate | $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ | 93·1 | 115 | ... | 0·207 | ... | ... |
| Cadmium sulphate | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ | 0·176 | 0·200 | 0·210 | 80·2 | ... | ... |
| Chlorine | $8\text{CdSO}_4 \cdot 3\text{H}_2\text{O}$ | 75·5 | 76·1 | ... | ... | ... | 60·8 |
| Cupric chloride. | $\text{CdSO}_4 \cdot \text{H}_2\text{O}$ | ... | ... | ... | ... | ... | ... |
| | $\text{Cl}_2 \cdot 8\text{H}_2\text{O}$ (up to 28·7°) | 0·51 | 1·3 | ... | ... | ... | ... |
| | $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ | 70·6 | 75 | 80 | ... | ... | ... |

TABLE 28—Continued.

| 100 parts of Water dissolve | | At 0°. | At 15°. | At 30°. | At 50°. | At 70°. | At 100°. |
|-----------------------------|---|--------|---------|---------|---------|---------|----------|
| SUBSTANCE. | SOLID PHASE. | | | | | | |
| Cupric nitrate . . . | $\left\{ \begin{array}{l} \text{Cu(NO}_3)_2 \cdot 6\text{H}_2\text{O} \\ \text{Cu(NO}_3)_2 \cdot 3\text{H}_2\text{O} \end{array} \right.$ | 81.8 | ca. 105 | ca. 155 | ca. 160 | ca. 192 | ca. 260 |
| sulphate . . . | $\left\{ \begin{array}{l} \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \\ \text{FeCl}_3 \cdot 6\text{H}_2\text{O} \end{array} \right.$ | 14.9 | 19.3 | 25.5 | 33.6 | 45.7 | 73.5 |
| Ferric chloride * | $\left\{ \begin{array}{l} \text{FeCl}_3 \cdot 6\text{H}_2\text{O} \\ \text{FeCl}_3 \cdot 7\text{H}_2\text{O} \end{array} \right.$ | 74.4 | 87 | 106.8 | ... | ... | 536 |
| Ferrous sulphate . . . | $\left\{ \begin{array}{l} \text{FeSO}_4 \cdot 7\text{H}_2\text{O} \\ \text{FeSO}_4 \cdot 4\text{H}_2\text{O} \end{array} \right.$ | 15.6 | 23.9 | 33.0 | 48.5 | ... | ... |
| Iodic acid . . . | $\left\{ \begin{array}{l} \text{FeSO}_4 \cdot 4\text{H}_2\text{O} \\ \text{HIO}_3 \end{array} \right.$ | 287 | 307 | 329 | 376 | 56.04 | ... |
| Iodine . . . | $\left\{ \begin{array}{l} \text{I}_2 \\ \text{PbCl}_2 \end{array} \right.$ | ... | 0.0276 | 0.0154 | ... | 446 | ... |
| Lead chloride . . . | $\left\{ \begin{array}{l} \text{PbCl}_2 \\ \text{Pb(NO}_3)_2 \end{array} \right.$ | 0.673 | 0.909 | 1.20 | 1.70 | 2.30 | 3.34 |
| nitrate . . . | $\left\{ \begin{array}{l} \text{Pb(NO}_3)_2 \\ \text{PbSO}_4 \cdot 3\text{H}_2\text{O} \end{array} \right.$ | 36.5 | 48.4 | 60.7 | 78.7 | 97.7 | 127 |
| sulphate . . . | $\left\{ \begin{array}{l} \text{PbSO}_4 \cdot 3\text{H}_2\text{O} \\ \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \end{array} \right.$ | ... | 0.004 | ... | ... | ... | ... |
| Magnesium carbonate . . . | $\left\{ \begin{array}{l} \text{MgCO}_3 \cdot 3\text{H}_2\text{O} \\ \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \end{array} \right.$ | 52.8 | 0.10 | 56 | 59 | 63 | 78 |
| chloride* . . . | $\left\{ \begin{array}{l} \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \\ \text{Mg(OH)}_2 \end{array} \right.$ | ... | 54 | ... | ... | ... | ... |
| hydroxide . . . | $\left\{ \begin{array}{l} \text{Mg(OH)}_2 \\ \text{MgSO}_4 \cdot 7\text{H}_2\text{O} \end{array} \right.$ | ... | 0.0008 | ... | ... | ... | ... |
| sulphate* . . . | $\left\{ \begin{array}{l} \text{MgSO}_4 \cdot 7\text{H}_2\text{O} \\ \text{K}_2\text{Cr}_2\text{O}_7 \end{array} \right.$ | 26.0 | 33.3 | 40.9 | ... | ... | ... |
| Potassium bichromate . . . | $\left\{ \begin{array}{l} \text{K}_2\text{Cr}_2\text{O}_7 \\ \text{KHC}_2\text{O}_4 \end{array} \right.$ | 5.0 | 10.5 | 21 | 40 | 61 | 102 |
| bicarbonate . . . | $\left\{ \begin{array}{l} \text{KHC}_2\text{O}_4 \\ \text{K}_2\text{CO}_3 \cdot 2\text{H}_2\text{O} \end{array} \right.$ | 22.5 | 30.5 | 39.0 | 52.2 | ... | ... |
| carbonate . . . | $\left\{ \begin{array}{l} \text{K}_2\text{CO}_3 \cdot 2\text{H}_2\text{O} \\ \text{KClO}_4 \end{array} \right.$ | 105 | 111 | 114 | 121 | 133 | 156 |
| chlorate . . . | $\left\{ \begin{array}{l} \text{KClO}_4 \\ \text{K}_2\text{CrO}_4 \end{array} \right.$ | 3.3 | 6.0 | 10.1 | 19.7 | 32.5 | 56.0 |
| chromate . . . | $\left\{ \begin{array}{l} \text{K}_2\text{CrO}_4 \\ \text{K}_3\text{Fe(CN)}_6 \cdot 3\text{H}_2\text{O} \end{array} \right.$ | 58.9 | 61.8 | 65.0 | 69.0 | 73.0 | 79.1 |
| ferricyanide . . . | $\left\{ \begin{array}{l} \text{K}_3\text{Fe(CN)}_6 \cdot 3\text{H}_2\text{O} \\ \text{K}_3\text{Fe(CN)}_6 \cdot 3\text{H}_2\text{O} \end{array} \right.$ | 31 | 40 | ... | ... | ... | 77.5 |
| ferrocyanide . . . | $\left\{ \begin{array}{l} \text{K}_3\text{Fe(CN)}_6 \cdot 3\text{H}_2\text{O} \\ \text{KOH} \cdot 2\text{H}_2\text{O} \end{array} \right.$ | 14 | 22 | ca. 30 | ca. 42 | ca. 60 | ... |
| hydroxide . . . | $\left\{ \begin{array}{l} \text{KOH} \cdot 2\text{H}_2\text{O} \\ \text{KI} \end{array} \right.$ | 97 | 107 | 126 | ... | ... | ... |
| iodide . . . | $\left\{ \begin{array}{l} \text{KI} \\ \text{KNO}_3 \end{array} \right.$ | 126 | 140 | 152 | 140 | ca. 152 | 178 |
| nitrate . . . | $\left\{ \begin{array}{l} \text{KNO}_3 \end{array} \right.$ | 13.3 | 25.7 | 45.8 | 85.5 | 184 | 209 |
| | | | | | | 188 | 246 |

* There are a number of hydrates and the solubility curves are somewhat complex.

TABLE 28—Continued.

| 100 parts of Water dissolve | | At 0°. | At 15°. | At 30°. | At 50°. | At 70°. | At 100°. |
|-----------------------------|---|--------|---------|---------|---------|---------|----------|
| SUBSTANCE. | SOLID PHASE. | | | | | | |
| Potassium permanganate . | KMnO_4 . | 2.9 | 6.3 | ... | ... | ... | ... |
| platinichloride . | K_2PtCl_6 . | 0.7 | 1.0 | 1.4 | 2.2 | 3.2 | 5.2 |
| sulphate . | K_2SO_4 . | 7.35 | 10.0 | 13.0 | 16.5 | 19.7 | 24.1 |
| Sodium borate (borax) . | $(\text{Na}_2\text{B}_4\text{O}_7, 10\text{H}_2\text{O})$ | 1.1 | 2.0 | 3.9 | 10.5 | 24.4 | 52.3 |
| bicarbonate . | $(\text{Na}_2\text{B}_4\text{O}_7, 5\text{H}_2\text{O})$ | ... | ... | ... | ... | ... | ... |
| bromide . | NaHCO_3 . | 6.9 | 8.9 | 11.1 | 14.5 | ... | ... |
| carbonate . | $\text{NaBr}, 2\text{H}_2\text{O}$. | 79.5 | 87 | 97 | 116 | 118 | 120.5 |
| chlorate . | NaBr . | ... | ... | ... | ... | ... | ... |
| chloride . | $(\text{Na}_2\text{CO}_3, 10\text{H}_2\text{O})$ | 7.1 | 16.6 | 40.9 | ... | ... | ... |
| hydroxide * . | $(\text{Na}_2\text{CO}_3, \text{H}_2\text{O})$ | ... | ... | ... | ... | ... | ... |
| nitrate . | NaClO_3 . | 82 | 91 | ... | 47.5 | 45.8 | 45.1 |
| nitrite . | NaCl . | 35.63 | 35.75 | 36.03 | 36.67 | 37.51 | 204 |
| phosphate (ordinary) | $\text{NaOH}, 4\text{H}_2\text{O}$. | 42 | ... | ... | ... | ... | 39.12 |
| sulphate . | $(\text{NaOH}, \text{H}_2\text{O})$ | ... | ... | ... | ... | ... | ... |
| sulphite . | NaNO_2 . | 73 | 105 | 119 | 145 | ... | ... |
| thiosulphate | NaNO_3 . | ... | 84 | 96 | 114 | 136 | 175 |
| Stannous chloride | $(\text{Na}_2\text{HPO}_4, 12\text{H}_2\text{O})$ | 2.5 | 6.0 | 24.1 | ... | ... | ... |
| Zinc chloride * | $(\text{Na}_2\text{HPO}_4, 7\text{H}_2\text{O})$ | ... | ... | ... | 84 | 95 | 99 |
| sulphate * | $(\text{Na}_2\text{SO}_4, 10\text{H}_2\text{O})$ | 5.0 | 13.2 | 40 | ... | ... | ... |
| | $(\text{Na}_2\text{SO}_4, 7\text{H}_2\text{O})$ | ... | ... | ... | 46.8 | 44.5 | 42.7 |
| | Na_2SO_3 . | 14.1 | ca 24 | ... | ... | ... | ... |
| | $\text{Na}_2\text{S}_2\text{O}_3, 5\text{H}_2\text{O}$. | 52 | 65 | 85 | ... | ... | ... |
| | $\text{Na}_2\text{S}_2\text{O}_3, 2\text{H}_2\text{O}$. | ... | ... | ... | 170 | 232 | 266 |
| | $\text{SnCl}_2, 2\text{H}_2\text{O}$. | 84 | 270 | ... | ... | ... | ... |
| | $\text{ZnCl}_2, 3\text{H}_2\text{O}$. | 208 | ... | ... | ... | ... | ... |
| | $\text{ZnSO}_4, 7\text{H}_2\text{O}$. | 41.9 | 50.9 | 61 | ... | ... | ... |

* There are a number of hydrates and the solubility curves are somewhat complex.

TABLE 29.—SOLUBILITY OF GASES IN WATER.

Column *a* gives the volume of gas (reduced to 0° and 760 mm.) dissolved by one volume of the liquid at the temperature indicated, if the partial pressure of the gas is = 760 mm. Hg.

Column *q* gives the weight of the substance in grams, dissolved by 100 gr. of the pure solvent, if the partial pressure of the gas + the vapour pressure of the liquid at the temperature indicated = 760 mm. Hg.

The letters following the name of the gas indicate the observer, viz., W. = Winkler; B. & B. = Bohr & Bock; F. = Fauser; R. = Raoult; S. = Schönfeld; R.-D. = Roscoe-Dittmar; R. = Roozeboom; B. = Bunsen.

| T. | Oxygen, W. | | Hydrogen, W. | | Nitrogen, B. & B. | | Chlorine, W. | |
|-----|------------|-----------|--------------|-----------|-------------------|-----------|--------------|-----------|
| | <i>a.</i> | <i>q.</i> | <i>a.</i> | <i>q.</i> | <i>a.</i> | <i>q.</i> | <i>a.</i> | <i>q.</i> |
| 0 | ·04890 | ·006948 | ·02148 | ·0001922 | ·02388 | ·002 977 | ... | ... |
| 1 | ·04759 | ·006758 | ·02126 | ·0001902 | ·02337 | ·002912 | ... | ... |
| 2 | ·04633 | ·006576 | ·02105 | ·0001882 | ·02288 | ·002843 | ... | ... |
| 3 | ·04512 | ·006401 | ·02084 | ·0001862 | ·02241 | ·002790 | ... | ... |
| 4 | ·04397 | ·006234 | ·02064 | ·0001843 | ·02196 | ·002732 | ... | ... |
| 5 | ·04286 | ·006074 | ·02044 | ·0001824 | ·02153 | ·002677 | ... | ... |
| 6 | ·04181 | ·005920 | ·02025 | ·0001806 | ·02111 | ·002624 | ... | ... |
| 7 | ·04080 | ·005775 | ·02007 | ·0001789 | ·02070 | ·002570 | ... | ... |
| 8 | ·03983 | ·005633 | ·01989 | ·0001772 | ·02031 | ·002520 | ... | ... |
| 9 | ·03891 | ·005499 | ·01972 | ·0001756 | ·01993 | ·002472 | ... | ... |
| 10 | ·03802 | ·005370 | ·01955 | ·0001739 | ·01956 | ·002424 | 3·095 | ·9969 |
| 11 | ·03718 | ·005248 | ·01940 | ·0001725 | ·01920 | ·002378 | 2·996 | ·9652 |
| 12 | ·03637 | ·005129 | ·01925 | ·0001710 | ·01885 | ·002333 | 2·900 | ·9344 |
| 13 | ·03560 | ·005011 | ·01911 | ·0001696 | ·01851 | ·002289 | 2·808 | ·9048 |
| 14 | ·03486 | ·004908 | ·01897 | ·0001682 | ·01818 | ·002246 | 2·720 | ·8766 |
| 15 | ·03415 | ·004804 | ·01883 | ·0001669 | ·01786 | ·002205 | 2·635 | ·8493 |
| 16 | ·03347 | ·004703 | ·01869 | ·0001654 | ·01755 | ·002164 | 2·553 | ·8230 |
| 17 | ·03283 | ·004609 | ·01856 | ·0001641 | ·01725 | ·002125 | 2·474 | ·7977 |
| 18 | ·03220 | ·004515 | ·01844 | ·0001630 | ·01698 | ·002089 | 2·399 | ·7736 |
| 19 | ·03161 | ·004428 | ·01831 | ·0001616 | ·01667 | ·002049 | 2·328 | ·7508 |
| 20 | ·03102 | ·004339 | ·01819 | ·0001604 | ·01639 | ·002012 | 2·260 | ·7291 |
| 21 | ·03044 | ·004253 | ·01805 | ·0001590 | ·01611 | ·001975 | 2·200 | ·7098 |
| 22 | ·02988 | ·004169 | ·01792 | ·0001575 | ·01584 | ·001940 | 2·143 | ·6916 |
| 23 | ·02934 | ·004088 | ·01779 | ·0001561 | ·01557 | ·001903 | 2·087 | ·6737 |
| 24 | ·02881 | ·004009 | ·01766 | ·0001548 | ·01530 | ·001868 | 2·035 | ·6570 |
| 25 | ·02831 | ·003932 | ·01754 | ·0001534 | ·01504 | ·001832 | 1·985 | ·6411 |
| 26 | ·02783 | ·003859 | ·01742 | ·0001522 | ·01478 | ·001798 | 1·937 | ·6257 |
| 27 | ·02736 | ·003787 | ·01731 | ·0001509 | ·01453 | ·001764 | 1·891 | ·6110 |
| 28 | ·02691 | ·003717 | ·01720 | ·0001497 | ·01428 | ·001731 | 1·848 | ·5973 |
| 29 | ·02649 | ·003653 | ·01709 | ·0001485 | ·01404 | ·001699 | 1·808 | ·5845 |
| 30 | ·02608 | ·003588 | ·01699 | ·0001470 | ·01380 | ·001666 | 1·769 | ·5722 |
| 35 | ·02440 | ·003315 | ·01666 | ·0001426 | ·01271 | ·001516 | 1·575 | ·5103 |
| 40 | ·02306 | ·003081 | ·01644 | ·0001385 | ·01182 | ·001386 | 1·414 | ·4589 |
| 45 | ·02187 | ·002860 | ·01624 | ·0001338 | ·01111 | ·001275 | 1·300 | ·4227 |
| 50 | ·02090 | ·002657 | ·01608 | ·0001288 | ·01061 | ·001184 | 1·204 | ·3927 |
| 60 | ·01946 | ·002274 | ·01600 | ·0001178 | ·01000 | ·001026 | 1·006 | ·3294 |
| 70 | ·01833 | ·001857 | ... | ·0001021 | ... | ... | 0·848 | ·2792 |
| 80 | ·01761 | ·001381 | ... | ·0000790 | ... | ... | 0·672 | ·2226 |
| 90 | ·01723 | ·000787 | ... | ·0000461 | ... | ... | 0·380 | ·1268 |
| 100 | ·01700 | ·000000 | ... | ·0000000 | ·01000 | ·000000 | 0·000 | ·0000 |

TABLE 29—*Continued.*

| T. | Carbon monoxide, W. | | Carbon dioxide, B. & B. | | Hydrogen sul- phide, F. | | Ammonia, R. | |
|-----|------------------------|----------|----------------------------|--------|----------------------------|-------|----------------|------|
| | a. | q. | a. | q. | a. | q. | a. | q. |
| 0 | 0·03537 | 0·004397 | 1·713 | 0·3347 | 4·686 | 0·710 | 1298·9 | 98·7 |
| 1 | 0·03455 | 0·004293 | 1·616 | 0·3214 | 4·555 | 0·689 | 1220·2 | 92·7 |
| 2 | 0·03375 | 0·004192 | 1·584 | 0·3091 | 4·428 | 0·670 | 1154·7 | 87·7 |
| 3 | 0·03297 | 0·004092 | 1·527 | 0·2979 | 4·303 | 0·651 | 1100·9 | 83·6 |
| 4 | 0·03222 | 0·003997 | 1·473 | 0·2872 | 4·182 | 0·632 | 1053·0 | 79·9 |
| 5 | 0·03149 | 0·003904 | 1·424 | 0·2774 | 4·063 | 0·615 | 1019·5 | 77·3 |
| 6 | 0·03078 | 0·003814 | 1·377 | 0·2681 | 3·948 | 0·596 | 997·2 | 75·6 |
| 7 | 0·03009 | 0·003726 | 1·331 | 0·2590 | 3·836 | 0·579 | 974·9 | 73·9 |
| 8 | 0·02942 | 0·003641 | 1·282 | 0·2494 | 3·728 | 0·562 | 954·5 | 72·3 |
| 9 | 0·02878 | 0·003560 | 1·237 | 0·2404 | 3·622 | 0·546 | 933·0 | 70·6 |
| 10 | 0·02816 | 0·003481 | 1·191 | 0·2319 | 3·520 | 0·530 | 910·4 | 68·9 |
| 11 | 0·02757 | 0·003416 | 1·151 | 0·2240 | 3·421 | 0·515 | 888·0 | 67·2 |
| 12 | 0·02701 | 0·003353 | 1·117 | 0·2166 | 3·325 | 0·500 | 865·6 | 65·5 |
| 13 | 0·02646 | 0·003260 | 1·083 | 0·2099 | 3·232 | 0·485 | 843·2 | 63·7 |
| 14 | 0·02593 | 0·003188 | 1·050 | 0·2033 | 3·142 | 0·471 | 822·1 | 62·1 |
| 15 | 0·02543 | 0·003130 | 1·019 | 0·1971 | 3·056 | 0·458 | 802·4 | 60·6 |
| 16 | 0·02494 | 0·003065 | 0·985 | 0·1904 | 2·973 | 0·445 | 783·2 | 59·1 |
| 17 | 0·02448 | 0·003007 | 0·956 | 0·1845 | 2·893 | 0·433 | 764·1 | 57·6 |
| 18 | 0·02402 | 0·002943 | 0·928 | 0·1789 | 2·816 | 0·421 | 744·3 | 56·1 |
| 19 | 0·02360 | 0·002893 | 0·902 | 0·1736 | 2·742 | 0·409 | 725·8 | 54·7 |
| 20 | 0·02319 | 0·002839 | 0·878 | 0·1689 | 2·672 | 0·398 | 710·6 | 53·5 |
| 21 | 0·02281 | 0·002789 | 0·854 | 0·1641 | ... | ... | 690·2 | 51·9 |
| 22 | 0·02244 | 0·002739 | 0·829 | 0·1591 | ... | ... | 674·3 | 50·6 |
| 23 | 0·02208 | 0·002691 | 0·804 | 0·1541 | ... | ... | 661·0 | 49·6 |
| 24 | 0·02174 | 0·002647 | 0·781 | 0·1494 | ... | ... | 647·8 | 48·6 |
| 25 | 0·02142 | 0·002603 | 0·759 | 0·1450 | ... | ... | 634·6 | 47·6 |
| 26 | 0·02110 | 0·002560 | 0·738 | 0·1407 | ... | ... | 621·3 | 46·5 |
| 27 | 0·02080 | 0·002519 | 0·718 | 0·1367 | ... | ... | 608·1 | 45·5 |
| 28 | 0·02051 | 0·002479 | 0·699 | 0·1328 | ... | ... | 594·8 | 44·4 |
| 29 | 0·02024 | 0·002442 | 0·682 | 0·1293 | ... | ... | ... | ... |
| 30 | 0·01998 | 0·002405 | 0·665 | 0·1259 | ... | ... | ... | ... |
| 35 | 0·01877 | 0·002231 | 0·592 | 0·1106 | ... | ... | ... | ... |
| 40 | 0·01775 | 0·002076 | 0·530 | 0·0974 | ... | ... | ... | ... |
| 45 | 0·01690 | 0·001934 | 0·479 | 0·0862 | ... | ... | ... | ... |
| 50 | 0·01615 | 0·001797 | 0·436 | 0·0762 | ... | ... | ... | ... |
| 60 | 0·01488 | 0·001521 | 0·359 | 0·0577 | ... | ... | ... | ... |
| 70 | 0·01440 | 0·001276 | ... | ... | ... | ... | ... | ... |
| 80 | 0·01430 | 0·000981 | ... | ... | ... | ... | ... | ... |
| 90 | 0·01420 | 0·000568 | ... | ... | ... | ... | ... | ... |
| 100 | 0·01410 | 0·000000 | ... | ... | ... | ... | ... | ... |

TABLE 29—Continued.

| T. | Sulphur dioxide, S. | | Hydrogen chloride, R.D. | | Methane, W. | |
|-----|------------------------|-------|----------------------------|------|-------------|----------|
| | a. | q. | a. | q. | a. | l. |
| 0 | 79.789 | 22.83 | 506.7 | 82.5 | 0.05563 | 0.003959 |
| 1 | 77.210 | 22.09 | ... | ... | 0.05401 | 0.003842 |
| 2 | 74.691 | 21.37 | 499.8 | 81.4 | 0.05244 | 0.003729 |
| 3 | 72.230 | 20.67 | ... | ... | 0.05093 | 0.003620 |
| 4 | 69.828 | 19.98 | 493.7 | 80.4 | 0.04946 | 0.003514 |
| 5 | 67.485 | 19.31 | ... | ... | 0.04805 | 0.003411 |
| 6 | 65.200 | 18.66 | 486.9 | 79.3 | 0.04669 | 0.003312 |
| 7 | 62.973 | 18.02 | ... | ... | 0.04539 | 0.003218 |
| 8 | 60.805 | 17.40 | 480.8 | 78.3 | 0.04413 | 0.003127 |
| 9 | 58.697 | 16.80 | ... | ... | 0.04292 | 0.003039 |
| 10 | 56.647 | 16.21 | 473.9 | 77.2 | 0.04177 | 0.002956 |
| 11 | 54.655 | 15.64 | ... | ... | 0.04072 | 0.002880 |
| 12 | 52.723 | 15.09 | 467.7 | 76.2 | 0.03970 | 0.002805 |
| 13 | 50.849 | 14.56 | ... | ... | 0.03872 | 0.002733 |
| 14 | 49.033 | 14.04 | 461.5 | 75.2 | 0.03779 | 0.002666 |
| 15 | 47.276 | 13.54 | ... | ... | 0.03690 | 0.002600 |
| 16 | 45.578 | 13.05 | 455.2 | 74.2 | 0.03606 | 0.002538 |
| 17 | 43.939 | 12.59 | ... | ... | 0.03525 | 0.002479 |
| 18 | 43.360 | 12.14 | 448.3 | 73.1 | 0.03446 | 0.002422 |
| 19 | 40.838 | 11.70 | ... | ... | 0.03376 | 0.002369 |
| 20 | 39.374 | 11.29 | 442.0 | 72.1 | 0.03308 | 0.002319 |
| 21 | 37.970 | 10.89 | ... | ... | 0.03243 | 0.002270 |
| 22 | 36.617 | 10.50 | 435.0 | 71.0 | 0.03180 | 0.002223 |
| 23 | 35.302 | 10.13 | ... | ... | 0.03119 | 0.002178 |
| 24 | 34.026 | 9.76 | 428.7 | 70.0 | 0.03061 | 0.002134 |
| 25 | 32.786 | 9.41 | ... | ... | 0.03006 | 0.002092 |
| 26 | 31.584 | 9.07 | 423.0 | 69.1 | 0.02952 | 0.002051 |
| 27 | 30.422 | 8.73 | ... | ... | 0.02901 | 0.002012 |
| 28 | 29.314 | 8.42 | 417.2 | 68.2 | 0.02852 | 0.001974 |
| 29 | 28.210 | 8.10 | ... | ... | 0.02806 | 0.001939 |
| 30 | 27.161 | 7.81 | 411.5 | 67.3 | 0.02762 | 0.001905 |
| 35 | 22.489 | 6.47 | ... | ... | 0.02546 | 0.001732 |
| 40 | 18.766 | 5.41 | 387.7 | 63.3 | 0.02369 | 0.001586 |
| 50 | ... | ... | 361.6 | 59.6 | 0.02134 | 0.001359 |
| 60 | ... | ... | 338.7 | 56.1 | 0.01954 | 0.001145 |
| 70 | ... | ... | ... | ... | 0.01825 | 0.000926 |
| 80 | ... | ... | ... | ... | 0.01770 | 0.000695 |
| 90 | ... | ... | ... | ... | 0.01735 | 0.000398 |
| 100 | ... | ... | ... | ... | 0.01700 | 0.000000 |

TABLE 29—*Continued.*

| T. | Ethylene, W. | | Acetylene, W. | | Air, W. | | Nitrous oxide, in Alcohol, B. |
|-----|--------------|--------|---------------|------|---------|-----|-------------------------------|
| | a. | q. | a. | q. | a. | | a. |
| 0 | 0·226 | 0·0281 | 1·73 | 0·20 | 0·02881 | ... | 4·1780 |
| 1 | 0·219 | 0·0272 | 1·68 | 0·19 | 0·02808 | ... | 4·1088 |
| 2 | 0·211 | 0·0262 | 1·63 | 0·19 | 0·02738 | ... | 4·0409 |
| 3 | 0·204 | 0·0254 | 1·58 | 0·18 | 0·02670 | ... | 3·9741 |
| 4 | 0·197 | 0·0245 | 1·53 | 0·18 | 0·02606 | ... | 3·9085 |
| 5 | 0·191 | 0·0237 | 1·49 | 0·17 | 0·02543 | ... | 3·8442 |
| 6 | 0·184 | 0·0228 | 1·45 | 0·17 | 0·02482 | ... | 3·7811 |
| 7 | 0·178 | 0·0221 | 1·41 | 0·16 | 0·02424 | ... | 3·7192 |
| 8 | 0·173 | 0·0214 | 1·37 | 0·16 | 0·02369 | ... | 3·6585 |
| 9 | 0·167 | 0·0207 | 1·34 | 0·15 | 0·02316 | ... | 3·5990 |
| 10 | 0·162 | 0·0200 | 1·31 | 0·15 | 0·02264 | ... | 3·5408 |
| 11 | 0·157 | 0·0194 | 1·27 | 0·15 | 0·02217 | ... | 3·4838 |
| 12 | 0·152 | 0·0188 | 1·24 | 0·14 | 0·02171 | ... | 3·4279 |
| 13 | 0·148 | 0·0183 | 1·21 | 0·14 | 0·02127 | ... | 3·3734 |
| 14 | 0·143 | 0·0176 | 1·18 | 0·14 | 0·02085 | ... | 3·3200 |
| 15 | 0·139 | 0·0171 | 1·15 | 0·13 | 0·02045 | ... | 3·2678 |
| 16 | 0·136 | 0·0167 | 1·13 | 0·13 | 0·02005 | ... | 3·2169 |
| 17 | 0·132 | 0·0162 | 1·10 | 0·13 | 0·01970 | ... | 3·1672 |
| 18 | 0·129 | 0·0158 | 1·08 | 0·12 | 0·01935 | ... | 3·1187 |
| 19 | 0·125 | 0·0153 | 1·05 | 0·12 | 0·01901 | ... | 3·0714 |
| 20 | 0·122 | 0·0150 | 1·03 | 0·12 | 0·01869 | ... | 3·0253 |
| 21 | 0·119 | 0·0146 | 1·01 | 0·12 | 0·01838 | ... | 2·9805 |
| 22 | 0·116 | 0·0142 | 0·99 | 0·11 | 0·01808 | ... | 2·9368 |
| 23 | 0·114 | 0·0139 | 0·97 | 0·11 | 0·01779 | ... | 2·8944 |
| 24 | 0·111 | 0·0135 | 0·95 | 0·11 | 0·01751 | ... | 2·8532 |
| 25 | 0·108 | 0·0131 | 0·93 | 0·11 | 0·01724 | ... | ... |
| 26 | 0·106 | 0·0129 | 0·91 | 0·10 | 0·01698 | ... | ... |
| 27 | 0·104 | 0·0126 | 0·89 | 0·10 | 0·01674 | ... | ... |
| 28 | 0·102 | 0·0123 | 0·87 | 0·10 | 0·01650 | ... | ... |
| 29 | 0·100 | 0·0121 | 0·85 | 0·10 | 0·01627 | ... | ... |
| 30 | 0·098 | 0·0118 | 0·84 | 0·09 | 0·01606 | ... | ... |
| ... | ... | ... | ... | ... | 0·01503 | ... | ... |
| ... | ... | ... | ... | ... | 0·01418 | ... | ... |
| ... | ... | ... | ... | ... | 0·01297 | ... | ... |
| ... | ... | ... | ... | ... | 0·01216 | ... | ... |
| ... | ... | ... | ... | ... | 0·01156 | ... | ... |
| ... | ... | ... | ... | ... | 0·01126 | ... | ... |
| ... | ... | ... | ... | ... | 0·01113 | ... | ... |
| ... | ... | ... | ... | ... | 0·01105 | ... | ... |

TABLE 30.—SPECIFIC GRAVITIES OF SOLIDS.

| | | | |
|--|-----------|-------------------------------------|-----------|
| Alum, ammonium | 1.626 | Cement | 2.7-3.05 |
| potassium | 1.724 | Charcoal, organic | 1.57 |
| Alum stone | 2.8 | wood | 0.3-0.5 |
| Alumina, anhydrous | 4.15 | China clay, kaolin | 2.21 |
| Aluminium, cast | 2.56 | Clay | 1.8-2.6 |
| wrought | 2.67 | Coal, porous | 1.16-1.63 |
| Aluminium sulphate, | | Coke, porous | 0.4 |
| cryst. | 1.596 | Concrete | 2.2 |
| Ammonium nitrate | 1.707 | Copper, hammered | 8.94 |
| sulphate | 1.77 | metallic, cast | 8.726 |
| chloride | 1.528 | oxide | 6.43 |
| Anhydrite (CaSO ₄) | 2.96 | pyrites | 4.1-4.3 |
| Anthracite | 1.4-1.7 | sulphate | 2.27 |
| Antimony | 6.7 | Cryolite | 2.96 |
| Arsenic acid | 4.250 | Cuprous sulphide | 5.97 |
| Arsenious acid | 3.884 | Ebonite | 1.38 |
| Asbestos | 2.45 | Elm wood | 0.58-0.67 |
| Ash wood | 0.7-0.8 | Fat, animal | 0.92 |
| Asphalt | 1.1-1.2 | Felspar | 2.5-2.6 |
| Barium carbonate | 4.56 | Fibres, vegetable | 1.51 |
| chloride, cryst. | 2.664 | Firebricks | 1.85 |
| hydroxide, cryst. | 1.66 | Fir wood, dry | 0.6 |
| sulphate (spar) | 4.73 | Flint | 2.6-2.7 |
| Basalt | 2.8-3.2 | Glass, crystal, Bohem. | 2.9-3.0 |
| Beech wood, dry | 0.7-0.8 | flint, English | 3.4-3.44 |
| Bell metal | 8.06 | green | 2.642 |
| Birch wood, dry | 0.7-0.8 | plate | 2.450 |
| Bismuth | 9.85 | Glauber's salt, anhydrous | 2.63 |
| Borate of magnesium | | cryst. | 1.52 |
| (boracite) | 2.9 | Granite | 2.5-2.9 |
| Borax, crystallised | 1.692 | Graphite | 2.35 |
| Boric acid, crystallised | 1.479 | Gypsum, cast, dry | 0.97 |
| fused | 1.830 | plaster-of-Paris | 2.322 |
| Brass | 8.4-8.7 | Hematite | 4.9 |
| Bricks, ordinary | 1.4-2.2 | Heavy spar | 4.3-4.48 |
| Brickwork | 1.5-1.7 | Ice (0°) | 0.917 |
| Brown coal, lignite | 1.2-1.4 | Iodine | 4.948 |
| Calamine | 4.1-4.5 | Iron, carbonate | 3.87 |
| Calcium carbonate | 2.7 | grey, cast | 6.6-7.3 |
| chloride, anhydrous | 2.240 | hydrated oxide | 3.94 |
| chloride, cryst. | 1.612 | magnetic oxide | 5.4 |
| phosphate | 3.18 | pyrites | 5.18 |
| silicate | 2.9 | pyrites, white | 4.65-4.88 |
| sulphate, anhydrous | 2.927 | sesquioxide | 5.22 |
| Calcspar | 2.72 | sulphate, cryst. | 1.904 |
| Cannel coal | 1.16-1.27 | white, cast | 7.1-7.9 |

TABLE 30—Continued.

| | | | |
|------------------------------|-----------|----------------------------|----------|
| Iron, wrought . . . | 7·8-7·9 | Potassium chloride . . . | 1·945 |
| Ivory . . . | 1·83-1·94 | chromate . . . | 2·603 |
| Larch wood . . . | 0·44-0·5 | hydroxide . . . | 2·044 |
| Lead, acetate, cryst. . . | 2·395 | nitrate . . . | 2·058 |
| carbonate . . . | 6·47 | sulphate . . . | 2·66 |
| cast . . . | 11·3 | Quartz . . . | 2·7 |
| chloride . . . | 5·802 | Resin . . . | 1·07 |
| chromate . . . | 6·00 | Rock salt . . . | 2·1-2·2 |
| nitrate . . . | 4·40 | Rubber . . . | 0·83 |
| oxide . . . | 9·41 | Sal-ammoniac . . . | 1·528 |
| red . . . | 8·62 | Sand, damp . . . | 1·9-2·0 |
| sulphate . . . | 6·169 | dry . . . | 1·4-1·6 |
| sulphide . . . | 7·505 | Sandstone . . . | 1·9-2·5 |
| Lignite . . . | 1·2-1·4 | Silver . . . | 10·6 |
| Lime, burnt, quick- . . . | 3·08 | Silver chloride . . . | 5·501 |
| Lime wood . . . | 0·5 | Slate . . . | 2·7 |
| Litharge . . . | 9·36 | Sodium carbonate, anh. . . | 2·509 |
| Magnesia, calcined . . . | 3·2 | carbonate, cryst. . . | 1·454 |
| carbonate . . . | 2·94 | chloride . . . | 2·078 |
| Magnesite . . . | 2·9-3·1 | hydroxide . . . | 2·130 |
| Magnesium chloride, . . . | | nitrate . . . | 2·226 |
| cryst. . . | 1·558 | sulphate . . . | 2·63 |
| Magnesium sulph., cryst. . . | 1·751 | sulphide . . . | 2·471 |
| Manganese native ore . . . | 4·7-5·0 | thiosulphate . . . | 1·736 |
| peroxide . . . | 2·94 | Spruce . . . | 0·52 |
| Maple wood . . . | 0·5-0·6 | Steel . . . | 7·80 |
| Marble . . . | 2·5-2·8 | Steel, cast . . . | 7·92 |
| Nickel, cast . . . | 8·28 | hardened . . . | 7·66 |
| hammered . . . | 8·67 | Sugar . . . | 1·6 |
| Oak, dry . . . | 0·85-0·95 | Sulphur, native . . . | 2·069 |
| Phosphor bronze, cast . . . | 8·6 | soft, amorphous . . . | 1·96 |
| drawn . . . | 8·72 | sticks, fresh . . . | 1·98 |
| Phosphorus, red . . . | 2·106 | sticks, old . . . | 2·05 |
| yellow . . . | 1·826 | Sulphuric anhydride . . . | 1·97 |
| Pine wood, red . . . | 0·5 | leak . . . | 0·80 |
| white . . . | 0·55 | Tin, cast . . . | 7·21-7·4 |
| yellow . . . | 0·76 | hammered . . . | 7·475 |
| Pitch . . . | 1·07 | Vulcanite . . . | 1·52 |
| Platinum . . . | 21·5 | Willow wood . . . | 0·5-0·58 |
| Poplar . . . | 0·38 | Witherite . . . | 4·30 |
| Porcelain . . . | 2·1-2·5 | Zinc, blende . . . | 3·9-4·2 |
| Porphyry . . . | 2·8 | cast . . . | 6·8 |
| Potash, natural . . . | 2·3 | oxide . . . | 5·73 |
| Potassium bisulphate . . . | 2·277 | rolled . . . | 7·2 |
| carbonate . . . | 2·264 | sulphate . . . | 2·036 |
| chlorate . . . | 2·35 | | |

TABLE 31.—SPECIFIC GRAVITY OF LIQUIDS.

| | Specific Gravity. | Temp. |
|--------------------------------------|-------------------|-------|
| Acetic anhydride | 1·004 | 17° |
| Acetone | 0·81 | ... |
| Alcohol | 0·7939 | 12°·5 |
| Acetic acid | 1·064 | 17° |
| Bisulphide of carbon | 1·272 | ... |
| Benzene | 0·884 | 15°·5 |
| Coal tar | 1·15 | 15° |
| Ether | 0·723 | 12°·5 |
| Glycerine | 1·260 | 15° |
| Linseed oil | 0·9347 | 15° |
| Mercury | 13·596 | 0° |
| Nitrogen peroxide (liquid) | 1·45 | ... |
| Olive oil | 0·917 | 15° |
| Petroleum | 0·78-0·81 | 15° |
| Rapeseed oil | 0·9136 | 15° |
| Sulphur dioxide (liquid) | 1·45 | 20° |
| Sea-water | 1·02-1·04 | 15° |
| Spirits of turpentine | 0·865 | 15° |

TABLE 32.—SPECIFIC GRAVITY AND PERCENT-AGE OF SOLUTIONS SATURATED AT 15°.

The percentage refers to Anhydrous Salt in 100 solution.

| | Tem-perature. | Percentage of Salt. | Specific Gravity. | Degrees Twaddell. |
|------------------------------|---------------|---------------------|-------------------|-------------------|
| Ammonium chloride | 15 | 26·30 | 1·0776 | 15·5 |
| sulphate | 19 | 50·00 | 1·2890 | 57·8 |
| Barium chloride | 15 | 25·97 | 1·2827 | 56·5 |
| Calcium chloride | 15 | 40·66 | 1·4110 | 82·2 |
| Magnesium sulphate | 15 | 25·25 | 1·2880 | 57·6 |
| Potassium chloride | 15 | 24·90 | 1·1723 | 34·4 |
| carbonate | 15 | 52·02 | 1·5708 | 114 |
| nitrate | 15 | 21·07 | 1·1441 | 28·8 |
| sulphate | 15 | 9·92 | 1·0331 | 16·6 |
| Sodium chloride | 15 | 26·395 | 1·2043 | 40·8 |
| carbonate | 15 | 14·35 | 1·1535 | 30·7 |
| nitrate | 19·5 | 46·25 | 1·3804 | 76 |
| sulphate | 15·0 | 11·95 | 1·1117 | 22·3 |

TABLE 33.—LINEAR EXPANSION OF
SUBSTANCES ON HEATING.

By heating from 0° to 100° C. (32°-212° F.).

| | | |
|------------------------------|----------|----------|
| Aluminium | 0·00218 | 1 : 459 |
| Brass | 0·001982 | 1 : 535 |
| Bronze | 0·001820 | 1 : 549 |
| Charcoal from oak | 0·001200 | 1 : 833 |
| fir | 0·00100 | 1 : 1000 |
| Copper | 0·001714 | 1 : 582 |
| Glass, flint | 0·000817 | 1 : 1219 |
| white | 0·000861 | 1 : 1161 |
| green | 0·000766 | 1 : 1305 |
| Gold | 0·001431 | 1 : 682 |
| Iron, wrought | 0·001235 | 1 : 812 |
| cast | 0·001144 | 1 : 901 |
| Lead | 0·002938 | 1 : 351 |
| Marble of Carrara | 0·000849 | 1 : 1178 |
| St Beat | 0·000418 | 1 : 2392 |
| Mercury | 0·0182 | 1 : 55 |
| Nickel | 0·001516 | 1 : 600 |
| Platinum | 0·000884 | 1 : 1132 |
| Porcelain (Berlin) | 0·000336 | 1 : 3000 |
| Silver | 0·001954 | 1 : 524 |
| Solder, hard | 0·002058 | 1 : 486 |
| Steel, hardened | 0·001240 | 1 : 807 |
| not hardened | 0·001079 | 1 : 927 |
| Tin | 0·002703 | 1 : 516 |
| Water | 0·015538 | 1 : 71·4 |
| Zinc | 0·001711 | 1 : 340 |

TABLE 34.—WEIGHT OF SUBSTANCES AS STORED.

| Substance. | 1 Cubic Metre Weighs | 1 Cubic Foot Weighs | Tons per Cub. Foot. |
|--|----------------------------|---------------------------|---------------------------|
| | Kilo. | lb. avdp. | |
| Alkali waste (wet) | 1268 | 79 | ·0352 |
| Bicarbonate (ground) | 986 | 61·5 | ·0274 |
| Black ash (lumps) | 962 | 60 | ·0268 |
| Bleaching powder | 721-834 | 45-52 | ·0216 |
| Bricks | 2100 | 131 | ·0584 |
| Cement | 1200 | 75 | ·0335 |
| Cinders (ashes) | 738 | 46 | ·0205 |
| Clay, damp | 1650 | 103 | ·0459 |
| Clay, dry | 1570 | 98 | ·0437 |
| Coke (for filling towers) | 417-534 | 26-33 | ·0131 |
| Flints (for filling towers) | 1600 | 100 | ·0446 |
| Limestone and other building stones | 2000 | 125 | ·0558 |
| Limestone dust | 1550 | 96·5 | ·0431 |
| Limestone (small pieces) | 1400 | 87·5 | ·0391 |
| Manganese dioxide, native | 2210 | 138 | ·0616 |
| Mortar (lime and sand) | 1800 | 112 | ·0500 |
| Nitre | 1310 | 81·5 | ·0364 |
| Nitre cake (acid sulphate of soda) | 1335 | 83 | ·0375 |
| Pyrites, broken pieces | 2500 | 156 | ·0696 |
| burnt | 1520 | 95 | ·0424 |
| smalls | 2340 | 146·5 | ·0654 |
| Quicklime | 1000 | 62·5 | ·0279 |
| Quicklime (small lumps) | 1058 | 66 | ·0295 |
| Salt | 689 | 43 | ·0192 |
| Saltcake | 1180 | 73·5 | ·0328 |
| Sand, dry | 1330 | 83 | ·0370 |
| damp | 1770 | 110 | ·0491 |
| Sieved lime (for bleaching powder) | 497-593 | 31-37 | ·0151 |
| Soda ash (unground) | 1195 | 74·5 | ·0332 |
| Soda crystals | 1010 | 63 | ·0281 |
| Soda salts (Na_2CO_3 , $10\text{H}_2\text{O}$) (drained) | 810 | 50·5 | ·0225 |
| Wood, beech logs | 400 | 24·5 | ·0107 |
| fir logs | 330 | 20·5 | ·0091 |
| oak logs | 420 | 26 | ·0116 |

TABLE 35.—WEIGHT OF SHEET METAL.

Weight in lbs. of one Square Foot.

| Thick- ness. | Wrought Iron. | Cast Iron. | Steel. | Copper. | Brass. | Lead. | Zinc. | Tin. | Gun- Metal. | Aluminium. |
|-----------------|------------------|---------------|--------|---------|--------|-------|-------|------|----------------|------------|
| Inch. | Lb. | Lb. | Lb. | Lb. | Lb. | Lb. | Lb. | Lb. | Lb. | Lb. |
| $\frac{1}{16}$ | 2.58 | 2.34 | 2.55 | 2.89 | 2.73 | 3.71 | 2.34 | 2.41 | 2.73 | 0.86 |
| $\frac{1}{8}$ | 5.05 | 4.69 | 5.10 | 5.78 | 5.47 | 7.42 | 4.69 | 4.81 | 5.46 | 1.72 |
| $\frac{3}{16}$ | 7.58 | 7.05 | 7.66 | 8.67 | 8.20 | 11.13 | 7.03 | 7.22 | 8.19 | 2.58 |
| $\frac{1}{4}$ | 10.10 | 9.38 | 10.21 | 11.76 | 10.94 | 14.83 | 9.38 | 9.63 | 10.9 | 3.45 |
| $\frac{5}{16}$ | 12.63 | 11.72 | 12.76 | 14.45 | 13.67 | 18.54 | 11.72 | 12.0 | 13.7 | 4.31 |
| $\frac{3}{8}$ | 15.16 | 14.06 | 15.31 | 17.34 | 16.41 | 22.25 | 14.06 | 14.4 | 16.4 | 5.18 |
| $\frac{7}{16}$ | 17.68 | 16.41 | 17.87 | 20.23 | 19.14 | 25.96 | 16.41 | 16.8 | 19.1 | 5.97 |
| $\frac{1}{2}$ | 20.21 | 18.75 | 20.42 | 23.13 | 21.88 | 29.67 | 18.75 | 19.3 | 21.9 | 6.91 |
| $\frac{9}{16}$ | 22.73 | 21.09 | 22.97 | 26.02 | 24.61 | 33.38 | 21.09 | 21.7 | 24.6 | 7.76 |
| $\frac{5}{8}$ | 25.27 | 23.44 | 25.52 | 28.91 | 27.34 | 37.08 | 23.44 | 24.0 | 27.4 | 8.64 |
| $\frac{11}{16}$ | 27.79 | 25.78 | 28.07 | 31.80 | 30.08 | 40.79 | 25.78 | 26.4 | 30.1 | 9.49 |
| $\frac{3}{4}$ | 30.31 | 28.13 | 30.68 | 34.69 | 32.81 | 44.50 | 28.13 | 28.8 | 32.8 | 10.36 |
| $\frac{13}{16}$ | 32.84 | 30.47 | 33.18 | 37.58 | 35.55 | 48.21 | 30.47 | 31.2 | 35.5 | 11.22 |
| $\frac{7}{8}$ | 35.37 | 32.81 | 35.73 | 40.47 | 38.23 | 51.92 | 32.81 | 33.6 | 38.2 | 12.09 |
| $\frac{15}{16}$ | 37.90 | 35.16 | 38.28 | 43.36 | 41.02 | 55.63 | 35.16 | 36.0 | 40.9 | 12.95 |
| 1 | 40.42 | 37.50 | 40.83 | 46.25 | 43.75 | 59.33 | 37.50 | 38.5 | 43.7 | 13.82 |

TABLE 86.—CHEMICAL NAMES AND FORMULÆ OF COMMON CHEMICALS.

| Common Name. | Chemical Name or Description. | Formula. |
|------------------------------|---|---|
| Abraum salts . . . | Residue from Stassfurt salts | |
| Acetic ether . . . | Ethyl acetate | $\text{CH}_3 \cdot \text{COOC}_2\text{H}_5$ |
| Alabaster | Fine grained masses of gypsum | $\text{CaSO}_4, 2\text{H}_2\text{O}$ |
| Aldehyde | Acetaldehyde | $\text{CH}_3 \cdot \text{CHO}$ |
| Alum | Potassium aluminium sulphate | $\text{KAl}(\text{SO}_4)_2, 12\text{H}_2\text{O}$ |
| Alundum | Essentially fused alumina | Al_2O_3 |
| Aniline | Amidobenzene | $\text{C}_6\text{H}_5 \cdot \text{NH}_2$ |
| Aniline salt | Aniline hydrochloride | $\text{C}_6\text{H}_5 \cdot \text{NH}_2 \cdot \text{HCl}$ |
| Animal charcoal . . . . . | ..... | Mixture of $\text{Ca}_3(\text{PO}_4)_2$ and C |
| Antifebrin | Acetanilide | $\text{C}_6\text{H}_5 \cdot \text{NHCOCH}_3$ |
| Antimony black | Antimony trisulphide | Sb_2S_3 |
| Antimony vermilion | Antimony oxysulphide | $\text{Sb}_2\text{S}_3 \cdot \text{Sb}_2\text{O}_3$ |
| Antimony white | Antimonious oxide | Sb_2O_3 |
| Antimony yellow | Basic lead antimoniate | $\text{PbO} \cdot \text{Sb}_2\text{O}_3$ |
| Aqua fortis | Concentrated nitric acid | HNO_3 |
| Aqua regia | Nitric acid + hydrochloric acid | $\text{HNO}_3 + 3\text{HCl}$ |
| Argol | Crude potassium bitartrate | $\text{KHC}_4\text{H}_4\text{O}_6$ |
| Arsine | Arsenuretted hydrogen | AsH_3 |
| Asphalt | Solution of pitch in heavy tar oils . . . . . | ..... |
| Asphaltum | Natural pitch from Trinidad | |
| Aspirin | Acetyl-salicylic acid | $\text{o-C}_6\text{H}_4(\text{OCOCH}_3)\text{COOH}$ |
| Azurite | Basic copper carbonate | $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ |
| Baking soda | Sodium bicarbonate | NaHCO_3 |
| Baryta | Barium oxide | BaO |
| Barytes | Native barium sulphate | BaSO_4 |
| Bauxite | Hydrated alumina | Hydrated Al_2O_3 |
| Benzine | Petrol . . . . . | ..... |
| Benzol | Benzene | C_6H_6 |
| Bichrome | Potassium bichromate | $\text{K}_2\text{Cr}_2\text{O}_7$ |
| Black ash | Impure sodium carbonate . . . . . | ..... |
| Black flux | Mixture of potassium carbonate and charcoal . . . . . | ..... |
| Black Jack | Native zinc sulphide | ZnS |
| Black lead | Graphite | C |
| Blanc fixe | Barium sulphate | BaSO_4 |
| Bleaching powder | Calcium chloro-hypochlorite | CaOCl_2 |

TABLE 36—*Continued.*

| Common Name | Chemical Name or Description. | Formula. |
|--------------------------|--|---|
| Blue-john . . . | Fluorspar (calcium fluoride) . . . | CaF_2 |
| Bluestone . . . | Copper sulphate . . . | $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ |
| Blue verditer . . . | Basic copper carbonate . . . | $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ |
| Blue vitriol . . . | Copper sulphate . . . | $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ |
| Bog iron . . . | Hydrated ferric oxide . . . | $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ |
| Bone ash . . . | Impure calcium phosphate . . . | mainly $\text{Ca}_3(\text{PO}_4)_2$ |
| Bone black . . . | Crude animal charcoal . . . | $\text{Ca}_3(\text{PO}_4)_2 + \text{C}$ |
| Borax . . . | Sodium tetraborate . . . | $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ |
| B.O.V. . . . | Crude 70 per cent. sulphuric acid . . . | ..... |
| Bremen blue . . . | Basic copper carbonate . . . | $x\text{CuCO}_3 \cdot y\text{Cu}(\text{OH})_2$ |
| Brimstone . . . | Sulphur . . . | S |
| Burnt alum . . . | Anhydrous potassium aluminium sulphate . . . | $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3$ |
| Burnt lime . . . | Calcium oxide . . . | CaO |
| Butter of antimony . . . | Antimony trichloride . . . | SbCl_3 |
| Cadmium yellow . . . | Cadmium sulphide . . . | CdS |
| Calamine . . . | Zinc carbonate . . . | ZnCO_3 |
| Caliche . . . | Impure sodium nitrate . . . | NaNO_3 |
| Calomel . . . | Mercurous chloride . . . | Hg_2Cl_2 |
| Cane sugar . . . | Sucrose . . . | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ |
| Carbolic acid . . . | Phenol . . . | $\text{C}_6\text{H}_5\text{OH}$ |
| Carbon black . . . | Carbon from American natural gas . . . | C |
| Carbonic acid . . . | Carbon dioxide . . . | CO_2 |
| Carborundum . . . | Silicon carbide . . . | SiC |
| Cassel Yellow . . . | Basic lead chloride . . . | Approx. $\text{PbCl}_2 + 7\text{PbO}$ |
| Cassiterite . . . | Native stannic oxide . . . | SnO_2 |
| Ceruse . . . | Basic lead carbonate . . . | $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$ |
| Celluloid . . . | Dinitro-cellulose with camphor . . . | ..... |
| Chalk . . . | Calcium carbonate . . . | CaCO_3 |
| Chili saltpetre . . . | Sodium nitrate . . . | NaNO_3 |
| China clay . . . | Aluminium silicate . . . | $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ |
| Chinese red . . . | Basic lead chromate . . . | $\text{PbCrO}_4 \cdot \text{PbO}$ |
| Chinese white . . . | Zinc oxide . . . | ZnO |
| Chloride of lime . . . | Bleaching powder . . . | CaOCl_2 |
| Chrome alum . . . | Potassium chromium sulphate . . . | $\text{K}_2\text{SO}_4 \cdot \text{Cr}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ |
| Chrome green . . . | Chromium oxide . . . | Cr_2O_3 |
| Chrome red . . . | Basic lead chromate . . . | $\text{PbCrO}_4 \cdot \text{PbO}$ |
| Chrome yellow . . . | Lead chromate . . . | PbCrO_4 |
| Cinnabar . . . | Mercuric sulphide . . . | HgS |
| Cobalt black . . . | Cobalt oxide . . . | CoO |

TABLE 36—Continued.

| Common Name. | Chemical Name or Description. | Formula. |
|-----------------------------|---|--|
| Cobalt green . . . | Cobalt zincate . . . | $\text{CoO} \cdot \text{ZnO}$ |
| Copperas . . . | Ferrous sulphate . . . | $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ |
| Corrosive sublimate . . . | Mercuric chloride . . . | HgCl_2 |
| Corundum . . . | Aluminium oxide . . . | Al_2O_3 |
| Cream of tartar . . . | Potassium hydrogen tartrate . . . | $\text{KHC}_4\text{H}_4\text{O}_6$ |
| Cresylic acid . . . | Mixture of <i>o</i> - <i>m</i> - and <i>p</i> -cresol . . . | $\text{C}_6\text{H}_4(\text{CH}_3)\text{OH}$ |
| Derby red . . . | Basic lead chromate . . . | $\text{PbCrO}_4 \cdot \text{PbO}$ |
| Derbyshire spar . . . | Fluorspar (calcium fluoride) . . . | CaF_2 |
| Dextrose . . . | Glucose . . . | $\text{C}_6\text{H}_{12}\text{O}_6$ |
| Dutch liquid . . . | Ethylene chloride . . . | $\text{C}_2\text{H}_4\text{Cl}_2$ |
| Eau-de-Javelle . . . | Potassium hypochlorite solution . . . | KClO |
| Eau-de-Labarraque . . . | Sodium hypochlorite solution . . . | NaClO |
| Emerald green . . . | Copper aceto-arsenite . . . | $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{CuAs}_2\text{O}_4$ |
| Emery . . . | Ferric oxide and corundum . . . | $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ |
| Epsom salts . . . | Magnesium sulphate . . . | $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ |
| Ferro-prussiate . . . | Potassium ferrocyanide . . . | $\text{K}_4\text{Fe}(\text{CN})_6$ |
| Firedamp . . . | Gas escaping from coal, mainly methane . . . | ..... |
| Flowers of sulphur . . . | Sulphur . . . | S |
| Fluorspar . . . | Calcium fluoride . . . | CaF_2 |
| Formalin . . . | 40 per cent. aqueous solution of formaldehyde . . . | $\text{H} \cdot \text{CHO}$ |
| Freezing salt . . . | Crude sodium chloride . . . | NaCl |
| Fruit sugar . . . | Fructose . . . | $\text{C}_6\text{H}_{12}\text{O}_6$ |
| Fulminating mercury . . . | Mercuric fulminate . . . | $\text{HgC}_2\text{O}_2\text{N}_2$ |
| Fuming oil of vitriol . . . | Fuming sulphuric acid . . . | A solution of SO_3 in H_2SO_4 |
| Gasoline . . . | American for petrol . . . | ..... |
| Glauber's salt . . . | Sodium sulphate . . . | $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ |
| Golden sulphide . . . | Antimony pentasulphide . . . | Sb_2S_5 |
| Grape sugar . . . | Glucose . . . | $\text{C}_6\text{H}_{12}\text{O}_6$ |
| Green verditer . . . | Basic copper carbonate . . . | $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ |
| Green vitriol . . . | Ferrous sulphate . . . | $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ |
| Gun cotton . . . | Cellulose trinitrate . . . | $\text{C}_6\text{H}_7\text{O}_2(\text{NO}_3)_3$ |
| Gypsum . . . | Calcium sulphate . . . | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ |
| Heavy spar . . . | Native barium sulphate . . . | BaSO_4 |
| Hexamine . . . | Hexamethylene tetramine . . . | $\text{C}_6\text{H}_{12}\text{N}_4$ |
| Horn silver . . . | Silver chloride . . . | AgCl |

TABLE 36—*Continued.*

| Common Name. | Chemical Name or Description. | Formula. |
|--------------------------------|---|---|
| Hypo | Sodium thiosulphate | $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ |
| Iceland spar | Pure native calcium carbonate | CaCO_3 |
| Indian red | Ferric oxide | Fe_2O_3 |
| Invert sugar | Glucose and fructose . . . . | ..... |
| Iron mordant | Ferric sulphate | $\text{Fe}_2(\text{SO}_4)_3$ |
| Ivory black | Purified bone char | $\text{Ca}_3(\text{PO}_4)_2$ and C |
| Kaolin | Aluminium silicate | $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ |
| Kerosene | American term for paraffin oil . . . . | ..... |
| Killed spirits of salt | Solution of zinc chloride | ZnCl_2 |
| King's yellow | Arsenic sulphide | As_2S_3 |
| Kish | Graphite scales from blast furnaces | C |
| Lævulose | Fructose | $\text{C}_6\text{H}_{12}\text{O}_6$ |
| Lampblack | Impure oily carbon . . . . | ..... |
| Lanolin | Cholesterol | $\text{C}_{27}\text{H}_{46}\text{O}$ |
| Laughing gas | Nitrous oxide | N_2O |
| Lemon chrome | Barium chromate | BaCrO_4 |
| Lime | Calcium oxide | CaO |
| Limeshells | Calcium oxide | CaO |
| Limestone | Calcium carbonate | CaCO_3 |
| Litharge | Lead monoxide | PbO |
| Lithopone | Zinc sulphide + barium sulphate | $\text{ZnS} + \text{BaSO}_4$ |
| Liver of sulphur | Mixed potassium sulphides . . . . | ..... |
| Loadstone | Magnetic iron oxide | Fe_3O_4 |
| Lunar caustic | Silver nitrate | AgNO_3 |
| Lye | Solution of sodium hydroxide | NaOH |
| Magnesia | Magnesium oxide | MgO |
| Magnesite | Magnesium carbonate | MgCO_3 |
| Malachite | Basic copper carbonate | $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ |
| Marble | Calcium carbonate | CaCO_3 |
| Marsh gas | Methane | CH_4 |
| Massicot | Lead monoxide | PbO |
| Metol | Photographic developer . . . . | ..... |
| Microcosmic salt | Sodium ammonium hydrogen phosphate | $\text{Na}(\text{NH}_4)\text{HPO}_4 \cdot 4\text{H}_2\text{O}$ |
| Milk of lime | Calcium hydroxide | $\text{Ca}(\text{OH})_2$ |
| Milk of magnesia | Magnesium hydroxide | $\text{Mg}(\text{OH})_2$ |
| Milk of sulphur | Precipitated sulphur | S |
| Milk sugar | Lactose | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ |
| Mineral white | Native calcium sulphate | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ |
| Minium | Lead tetroxide | Pb_3O_4 |

TABLE 36—Continued.

| Common Name. | Chemical Name or Description. | Formula. |
|----------------------------|--|--|
| Mixed acid . . . | Mixture of concentrated sulphuric and nitric acids | ..... |
| Mosaic gold . . . | Stannic sulphide . . . | SnS_2 |
| Moulder's blacking . . . | Ground coke or coal . . . | ..... |
| Muriate of ammonia . . . | Ammonium chloride . . . | NH_4Cl |
| Muriatic acid . . . | Hydrochloric acid . . . | HCl |
| Naples Yellow . . . | Basic lead pyro-antimonate . . . | |
| Natron . . . | Sodium carbonate . . . | $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ |
| Nitre . . . | Potassium nitrate . . . | KNO_3 |
| Nitre cake . . . | Sodium sulphate and bisulphate . . . | $\text{Na}_2\text{SO}_4 + \text{NaHSO}_4$ |
| Nitro-lime. . . . | Calcium cyanamide . . . | CaCN_2 |
| Nitrous ether . . . | Ethyl nitrite . . . | $\text{C}_2\text{H}_5\text{NO}_2$ |
| Nordhausen acid . . . | Fuming sulphuric acid . . . | $\text{H}_2\text{SO}_4 + \text{SO}_3$ |
| Norge saltpetre . . . | Basic calcium nitrate . . . | $\text{Ca}(\text{OH})(\text{NO}_2)$ |
| Oil of bitter almonds. . . | Benzaldehyde . . . | $\text{C}_6\text{H}_5 \cdot \text{CHO}$ |
| Oil of mirbane . . . | Nitrobenzene . . . | $\text{C}_6\text{H}_5 \cdot \text{NO}_2$ |
| Oil of mustard . . . | Allyl isothiocyanate . . . | $\text{C}_3\text{H}_5 \cdot \text{CNS}$ |
| Oil of vitriol . . . | Concentrated sulphuric acid . . . | H_2SO_4 |
| Oil of wintergreen . . . | Methylsalicylate . . . | $o\text{-C}_6\text{H}_4(\text{OH})\text{COOCH}_3$ |
| Olefiant gas . . . | Ethylene . . . | C_2H_4 |
| Oleum . . . | Fuming sulphuric acid . . . | $\text{H}_2\text{SO}_4 + \text{SO}_3$ |
| Orpiment . . . | Arsenic sulphide . . . | As_2S_3 |
| Paris green . . . | Copper aceto-arsenite . . . | $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{CuAs}_2\text{O}_4$ |
| Pearl ash . . . | Potassium carbonate . . . | K_2CO_3 |
| Perhydrol . . . | Trade name for hydrogen peroxide . . . | H_2O_2 |
| Permanent white . . . | Barium sulphate . . . | BaSO_4 |
| Petroleum ether . . . | Petrol . . . | ..... |
| Petroleum spirit . . . | Petrol . . . | ..... |
| Phenic acid . . . | Phenol . . . | $\text{C}_6\text{H}_5\text{OH}$ |
| Phosgene . . . | Carbonyl chloride . . . | COCl_2 |
| Picric acid . . . | <i>sym</i> -Trinitrophenol . . . | $\text{C}_6\text{H}_2(\text{NO}_2)_3\text{OH}$ |
| Pink salt . . . | Stannic ammonium chloride . . . | $(\text{NH}_4)_2\text{SnCl}_6$ |
| Plaster of Paris . . . | Calcium sulphate . . . | $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ |
| Plumbago . . . | Graphite . . . | C |
| Potash . . . | Potassium hydroxide . . . | KOH |
| Precipitated chalk . . . | Calcium carbonate . . . | CaCO_3 |
| Prussian blue . . . | Ferric ferrocyanide . . . | $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$ |
| Prussic acid . . . | Hydrocyanic acid . . . | HCN |
| Putty powder . . . | Stannic oxide . . . | SnO_2 |
| Pyrites . . . | Iron disulphide . . . | FeS_2 |
| Pyroligneous acid . . . | Crude acetic acid . . . | CH_3COOH |

TABLE 36—*Continued.*

| Common Name. | Chemical Name or Description. | Formula. |
|-------------------------------|---|--|
| Pyroligneous spirit . . . | Methyl alcohol . . . | CH_3OH |
| Pyrolusite . . . | Manganese dioxide . . . | MnO_2 |
| Quick lime . . . | Calcium oxide . . . | CaO |
| Quicksilver . . . | Mercury . . . | Hg |
| Quinol . . . | Hydroquinone . . . | $p - \text{C}_6\text{H}_4(\text{OH})_2$ |
| Realgar . . . | Arsenic disulphide . . . | As_2S_2 |
| Rectified spirit . . . | Ethyl alcohol, 90 per cent. | ..... |
| Red lead . . . | Lead tetroxide . . . | Pb_3O_4 |
| Red liquor . . . | Impure ferric chloride solution . . . | ..... |
| Red oxide . . . | Mainly ferric oxide . . . | Fe_2O_3 |
| Red prussiate of potash . . . | Potassium ferricyanide . . . | $\text{K}_3\text{Fe}(\text{CN})_6$ |
| Rochelle salt . . . | Potassium sodium tartrate . . . | $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ |
| Rock oil . . . | Petroleum . . . | ..... |
| Rock salt . . . | Native sodium chloride . . . | ..... |
| Rongalite . . . | Sodium formaldehyde sulphonylate . . . | $\text{NaOS} \cdot \text{O} \cdot \text{CH}_2\text{OH}$ |
| Rouge . . . | Ferric oxide . . . | ..... |
| R.O.V. . . . | Crude concentrated sulphuric acid . . . | ..... |
| Saccharin . . . | Benzoic sulphimide . . . | $o\text{-C}_6\text{H}_4 \begin{array}{c} \nearrow \text{SO}_2 \searrow \\ \nwarrow \text{CO} \nearrow \end{array} \text{NH}$ |
| Salammoniac . . . | Ammonium chloride . . . | NH_4Cl |
| Salol . . . | Phenyl salicylate . . . | $o\text{-C}_6\text{H}_4(\text{OH})\text{COOC}_6\text{H}_5$ |
| Salt cake . . . | Impure sodium sulphate . . . | ..... |
| Salt of amber . . . | Succinic acid . . . | $\text{C}_4\text{H}_6\text{O}_4$ |
| Salt of lemon . . . | Potassium hydrogen oxalate . . . | $\text{KHC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ |
| Salt of sorrel . . . | Potassium carbonate . . . | K_2CO_3 |
| Salt of tartar . . . | Potassium nitrate . . . | KNO_3 |
| Saltpetre . . . | 3·3' - Diamino - 4·4' - dihydroxy - arsenobenzene dihydrochloride . . . | $\text{As}_2[\text{C}_6\text{H}_3(\text{OH})(\text{NH}_2)_3] \cdot 2\text{HCl}$ |
| Salvarsan . . . | | |
| Satin white . . . | Calcium sulphate . . . | $\text{CaSO}_4, 2\text{H}_2\text{O}$ |
| Scheele's green . . . | Copper hydrogen arsenite . . . | CuHAsO_3 |
| Slaked lime . . . | Calcium hydroxide . . . | ..... |
| Smelling salt . . . | Ammonium carbonate . . . | Mainly $(\text{NH}_4)_2\text{CO}_3$ |
| Snow white . . . | Zinc oxide . . . | ZnO |
| Soda . . . | Sodium carbonate . . . | $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ |
| Soda water . . . | Water charged with CO_2 . . . | ..... |
| Sodium hyposulphite . . . | Sodium thiosulphate . . . | $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ |
| Soft soap . . . | Formerly potash soap, now many substitutes . . . | ..... |

TABLE 36—Continued.

| Common Name. | Chemical Name or Description. | Formula. |
|----------------------------------|--|--|
| Soluble glass . . . | Sodium silicate . . . | Na_2SiO_3 |
| Spirit of hartshorn . . . | Ammonia solution . . . | NH_4OH |
| Spirit of salt . . . | Hydrochloric acid . . . | HCl |
| Spirit of wine . . . | Ethyl alcohol . . . | $\text{C}_2\text{H}_5\text{OH}$ |
| Sugar of lead . . . | Lead acetate . . . | $\text{Pb}(\text{CH}_3\text{COO})_2, 3\text{H}_2\text{O}$ |
| Sulphuric ether . . . | Diethyl ether . . . | $(\text{C}_2\text{H}_5)_2\text{O}$ |
| Tartar . . . | Crude potassium bi-tartrate . . . | $\text{KHC}_4\text{H}_4\text{O}_6$ |
| Tartar emetic . . . | Potassium antimonyl tartrate . . . | $\text{K}(\text{SbO})\text{C}_4\text{H}_4\text{O}_6, \frac{1}{2}\text{H}_2\text{O}$ |
| Tetralin . . . | Tetrahydronaphthalene . . . | $\text{C}_{10}\text{H}_{12}$ |
| Thermit . . . | Mixture of iron oxide and aluminium . . . | |
| Tin salt . . . | Stannous chloride . . . | $\text{SnCl}_2, 2\text{H}_2\text{O}$ |
| Tin stone . . . | Native stannic oxide . . . | SnO_2 |
| Tin white . . . | Stannic hydroxide . . . | $\text{Sn}(\text{OH})_4$ |
| T. N. T. . . . | Trinitrotoluene . . . | $\text{C}_6\text{H}_2(\text{CH}_3)(\text{NO}_2)_3$ (1 . 2 . 4 . 6) |
| Toluol . . . | Toluene . . . | $\text{C}_6\text{H}_5, \text{CH}_3$ |
| Turnbull's blue . . . | Ferrous ferri cyanide . . . | $\text{Fe}_4[\text{Fe}(\text{CN})_6]_2$ |
| Ultramarine yellow . . . | Barium chromate . . . | BaCrO_4 |
| Vanillin . . . | Methyl ether of protocatechualdehyde . . . | $\begin{array}{l} \text{CHO} \\ \diagup \quad \diagdown \\ \text{C}_6\text{H}_3 \quad \text{---} \quad \text{OCH}_3 \\ \diagdown \quad \diagup \\ \text{OH} \end{array}$ <div style="display: flex; justify-content: flex-end; align-items: center; margin-top: -10px;"> <div style="margin-right: 10px;">1</div> <div style="margin-right: 10px;">3</div> <div>4</div> </div> |
| Vaseline . . . | Purified low - melting paraffin . . . | $(\text{C}_{18}\text{H}_{38} \text{ to } \text{C}_{21}\text{H}_{44})$ |
| Venetian red . . . | Ferric oxide . . . | Fe_2O_3 |
| Verdigris . . . | Basic copper acetate . . . | $2\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2 + \text{CuO}$ |
| Vermilion . . . | Red mercuric sulphide . . . | HgS |
| Vitriol . . . | Sulphuric acid . . . | H_2SO_4 |
| Washing soda . . . | Sodium carbonate . . . | $\text{Na}_2\text{CO}_3, 10\text{H}_2\text{O}$ |
| Water glass . . . | Solution of sodium silicates . . . | ..... |
| White arsenic . . . | Arsenious oxide . . . | As_2O_3 |
| White lead . . . | Basic lead carbonate . . . | $2\text{PbCO}_3 + \text{Pb}(\text{OH})_2$ |
| White vitriol . . . | Zinc sulphate . . . | $\text{ZnSO}_4, 7\text{H}_2\text{O}$ |
| Whiting . . . | Calcium carbonate . . . | CaCO_3 |
| Wood alcohol . . . | Methyl alcohol . . . | CH_3OH |
| Wood naphtha . . . | Crude methyl alcohol . . . | CH_3OH |
| Wood spirit . . . | Methyl alcohol . . . | CH_3OH |
| Yellow prussiate of potash . . . | Potassium ferrocyanide . . . | $\text{K}_4\text{Fe}(\text{CN})_6, 3\text{H}_2\text{O}$ |
| Zinc vitriol . . . | Zinc sulphate . . . | $\text{ZnSO}_4, 7\text{H}_2\text{O}$ |
| Zinc white . . . | Zinc oxide . . . | ZnO |

TABLE 37.—COMPOSITION OF COMMON ALLOYS.

| | | m.p.t. 1000° |
|------------------------------|---|-----------------|
| Aluminium bronze | 90 Cu, 10 Al | ... |
| Argozoil | 14 Ni, 54 Cu, 28 Zn, 2 Pb, 2 Sn | ... |
| Babitt metal | 90 Sn, 7 Sb, 3 Cu | ... |
| Bell metal | 77-85 Cu, 15-23 Sn | ... |
| Benedict metal | 14-16 Ni, 84-86 Cu | ... |
| Brass (for casting) | 33 Zn, 67 Cu | ... |
| (sheet) | 36-46 Zn, 54-64 Cu (sometimes Pb, Sn) | ... |
| (naval brass) | 37 Zn, 62 Cu, 1 Sn | ... |
| Brittania metal | 5-8 Sb, trace Pb; remainder Sn | ... |
| Bronze coinage (old) | 95 Cu, 4 Sn, 1 Zn | ... |
| (present) | 95½ Cu, 3 Sn, 1½ Zn | ... |
| Cast iron (white) | 3 combined C, 0·1 free C, traces Si, S, P, Mn; re- mainder Fe | ... |
| (grey) | 0·9 combined C, 2·8 free C, traces Si, S, P, Mn; re- mainder Fe | ... |
| Constantan | 40 Ni, 60 Cu | 1290° |
| Delta metal | 40 Zn, 1-2 Fe; remainder Cu . | ... |
| Dental alloy (1st quality) . | 66 Ag, 33 Pt | ... |
| (2nd quality) | 75 Ag, 25 Pt | ... |
| Ferro-chrome | 60-68 Cr, 2-5 C, 30-38 Fe . | ... |
| manganese | 40-80 Mn, 5-8 C, 12-55 Fe . | ... |
| nickel | 25-75 Ni, 1 C, 24-74 Fe . . | ... |
| silicon | 10-50 Si; remainder Fe . . | ... |
| German silver | 50-60 Cu, 10-30 Ni, 20-30 Zn . | 1100° |
| Gold coinage (British) . . . | 22 Au, 2 Cu or Ag | ... |
| Gun metal | 90 Cu, 10 Sn | ... |
| metal | 80-95 Cu, 5-18 Sn, 0-15 Zn, 0-10 Pb | ... |
| Illium | 60·6 Ni, 6·4 Cu, 21·1 Cr, 4·7 Mo, 2·1 W | 1300° |
| Invar | 35 Ni, 0·5 Mn, 0·5 C, 64 Fe . | 1425° |
| Magnalium | 90 Al, 10 Mg | ... |
| Manganin | 4-40 Ni, 60-80 Cu, 1-12 Mn . | ... |
| Monel metal | 60 Ni, 33 Cu, 6·5 Fe, 0·5 Al . | 1360° |
| Muntz metal | 40 Zn, 60 Cu | ... |
| Newton's metal | 18·75 Sn, 81·35 Pb, 50 Bi . . | 94·5° |
| Nichrome | 60 Ni, 14 Cr, 15 Fe | ... |
| Nickel coinage | Usually 25 Ni, 75 Cu | ... |
| Nickelin | 82 Ni, 55-70 Cu, 0-13 Zn . . | ... |
| Pewter | 79 Sn, 20 Pb, 1 Sb | ... |

TABLE 37—*Continued.*

| | | <i>m.p.t.</i> |
|--|--|---------------|
| Phosphor bronze (for strength) (for bearings) | 91-92 Cu, 7·4-8·7 Sn, 0·3-0·6 P 10-15 Sn, 1·0 P, 10 Sb or Pb; remainder Cu | ... |
| Platinite | 46 Ni, 0·15 C; remainder Fe | ... |
| Platinoid | 60 Cu, 14 Ni, 24 Zn, 1·2 W | ... |
| Rose's metal | 25 Sn, 25 Pb, 50 Bi | 95° |
| Silver coinage (old) | 92·5 Ag, 7·5 Cu | ... |
| (new) | 50·0 Ag, 50·0 Ni | ... |
| Solder (hard) | 25-50 Sn, 50-75 Pb | ... |
| (soft) | 67 Sn, 33 Pb | 182° |
| Speculum metal | 68 Cu, 32 Sn | ... |
| Stainless steel | 10-15 Cr, 0·5 C, 85-90 Fe | ... |
| Stellite (a "stainless steel") | 75 Co, 25 Cr (usually traces W) | ... |
| Stereotype metal | 112 Pb, 3 Sn, 18 Sb | ... |
| Tantiron | 84 Fe, 15 Si, 1 C | ... |
| Type metal | 15-20 Sb, 80-85 Pb; often little Sn or Bi | ... |
| Wood's alloy | 12 Cd, 50 Bi, 25 Pb, 13 Sn | 60·5° |

TABLE 38.—ACID-RESISTING CEMENTS.

Cottrell (**Nitric Acid and Nitrates**) recommends the following:—

Silicate Cement (Hard) for permanent joints. Coarse white asbestos powder made into a stiff dough with silicate of soda (Sp. Gr. 1·250).

Rust Cement for permanent iron to iron connections. 5 lbs. iron filings, 1 oz. sal ammoniac, 2 oz. flowers of sulphur, and sufficient water to make the mixture feel just damp.

Soft Putty for joints exposed to nitric acid or its vapour. Mix thoroughly 40 parts white asbestos powder, 8 parts blue asbestos fibre, 10 parts china clay, 2½ parts tallow and 21 parts of boiled linseed oil.

TABLE 39.—FREEZING MIXTURES.

| Substances. | Parts by Weight. | Temp. falls | | Substances. | Parts by Weight. | Temp. falls | |
|--|--------------------------|-------------|------|--|--------------------------|-------------|------|
| | | From | To | | | From | To |
| 1. Sodium sulphate . Ammonium nitrate . Dilute nitric acid . | 6 } 5 } 4 } | 10° | -25° | 7. Dilute nitric acid . Snow | 1 } 1 } | 14° | -35° |
| 2. Ammonium chloride . Potassium nitrate . Water | 5 } 5 } 16 } | 10° | -12° | 8. Sodium sulphate . Hydrochloric acid . Ammonium nitrate . Water | 8 } 5 } 1 } 1 } | 10° | -18° |
| 3. Sodium sulphate . Dilute nitric acid . | 3 } 2 } | 10° | -10° | 10. Potassium hydroxide . Snow | 4 } 3 } | 0° | -37° |
| 4. Sodium sulphate . Ammonium chloride . Potassium nitrate . Dilute nitric acid . | 6 } 4 } 2 } 4 } | 10° | -23° | 11. Dilute nitric acid . Dilute sulphuric acid . Snow | 1 } 1 } 2 } | 0° | -40° |
| 5. Sodium chloride . Snow | 1 } 3 } | 0° | -18° | 12. Dilute sulphuric acid . Snow | 1 } 1 } | 5° | -41° |
| 6. Ammonium chloride . Potassium nitrate . Water | 1 } 1 } 1 } | 5° | -24° | 13. Calcium chloride . Snow | 3 } 2 } | 0° | -33° |
| | | | | 14. Calcium chloride . Snow | 2 } 1 } | 0° | -42° |

TABLE 40.—SPECIFIC HEATS.

(a) Of Solids and Liquids.

| | | | |
|--------------------------------|--------|--------------------------|--------|
| Aluminium . . . | 0·2220 | Iron (cast) . . . | 0·1050 |
| Alcohol . . . | 0·547 | (wrought) . . . | 0·1081 |
| Antimony . . . | 0·0495 | Lead . . . | 0·0309 |
| Ashes . . . | 0·20 | Limestone (marble) . . . | 0·21 |
| Bismuth . . . | 0·0303 | Mercury . . . | 0·0334 |
| Brass . . . | 0·0917 | Nickel . . . | 0·109 |
| Bricks . . . | 0·22 | Oil (lubricating) . . . | 0·40 |
| Cement . . . | 0·19 | Platinum . . . | 0·0324 |
| Carbon (wood) . . . | 0·1653 | Sandstone . . . | 0·22 |
| (graphite) . . . | 0·1604 | Slag . . . | 0·18 |
| (diamond) . . . | 0·1042 | Silver . . . | 0·0559 |
| Copper . . . | 0·0936 | Steel . . . | 0·1070 |
| Glass (for thermometers) . . . | 0·1988 | Sulphur . . . | 0·1764 |
| Gypsum . . . | 0·20 | Sulphuric acid . . . | 0·332 |
| Granite . . . | 0·20 | Tin . . . | 0·0552 |
| Gold . . . | 0·0316 | Zinc . . . | 0·0935 |

(b) Of Gases and Vapours for Constant Pressures between the Temperatures of 0° and 200° C. (Langen and Regnault.)

| | Cal. per 1 kg. | Cal. per 1 cb.m. | | Cal. per 1 kg. | Cal. per 1 cb.m. |
|-----------------------|-------------------|---------------------|-----------------------|-------------------|---------------------|
| Atmospheric air . . . | 0·2389 | 0·3082 | Carbon monoxide . . . | 0·2466 | 0·3082 |
| Oxygen . . . | 0·2158 | 0·3082 | Methane . . . | 0·5930 | 0·4241 |
| Nitrogen . . . | 0·2459 | 0·3082 | Ethylene . . . | 0·4040 | 0·5053 |
| Hydrogen . . . | 3·452 | 0·3082 | Sulphur dioxide . . . | 0·1544 | 0·4413 |
| Carbon dioxide . . . | 0·2092 | 0·4109 | Aqueous vapour . . . | 0·4542 | 0·3654 |

TABLE 41.—MELTING POINTS (OF COMMON SUBSTANCES).

| | Degrees Cent. |
|--------------------------------|------------------|
| Alcohol (ethylic) | - 130 |
| Aluminium | 657 |
| Ammonia | - 75 |
| Antimony | 630 |
| Asphalt | 100 |
| Benzene (pure) | 6 |
| Bismuth | 268 |
| Boric acid | 186 |
| Brass | 900 |
| Bromine | - 70 |
| Bronze | 900 |
| Cadmium | 321 |
| Carbon dioxide | - 79 |
| Cobalt | 1190 |
| Colophonium | 135 |
| Copper | 1083 |
| Cupric chloride | 498 |
| Cuprous chloride | 434 |
| Fat, ox | 40 |
| sheep | 42 |
| pig | 27 |
| Fluorspar * | 1330-1378 |
| Glass free from lead | 1200 |
| containing lead | 1000 |
| Gold | 1063 |
| Iron, cast, white | 1075-1135 |
| grey | 1200-1250 |
| wrought | 1500 |
| Iodine | 113 |
| Lead | 327 |
| oxide | 954 |
| chloride | 498 |
| Magnesium | 650 |
| Mercury | 39.4 |
| Mercuric chloride * | 287-293 |
| Naphthalene | 79 |
| Nickel | 1452 |
| Nitric acid | - 50 |
| oxide | - 148.8 to - 167 |
| Nitric tetroxide | - 11 |
| Nitrous oxide | - 102 |

* The statements found in literature vary between these limits.

TABLE 42.—BOILING POINTS.

| | Degrees Centigrade. |
|---|------------------------|
| Acetone | 56 |
| Alcohol, absolute | 78 |
| Aldehyde | 21 |
| Ammonia, anhydrous | -33·7 |
| nitrate, satur. solution | 240 |
| Barium chloride, satur. solution | 101·4 |
| Benzene | 80·4 |
| Bromine | 63·0 |
| Calcium chloride, satur. solution | 260 |
| 66 per cent. solution | 156 |
| 33 per cent. solution | 128 |
| nitrate, satur. solution | 151 |
| Carbon dioxide | -78 |
| disulphide | 46 |
| Chlorine | -33·6 |
| Ether | 35 |
| Hydrochloric acid, 20·2 per cent. HCl | 110 |
| Iodine | 181·4 |
| Methylic alcohol | 60 |
| Mercury | 356 |
| Naphthalene | 218 |
| Nitric acid, very concentrated | 86 |
| specific gravity 1·42 | 121 |
| Nitrous anhydride | 3·5 |

TABLE 42—*Continued.*

| | Degrees Centigrade. |
|---|------------------------|
| Nitrous oxide | - 88 |
| Nitric peroxide | 20 |
| Potassium chloride, satur. solution | 108·5 |
| chlorate, satur. solution | 104·4 |
| acetate, satur. solution | 161 |
| carbonate, satur. solution | 133·5 |
| nitrate, satur. solution | 115 |
| sulphate, satur. solution | 102·1 |
| Sodium chloride, satur. solution | 108·8 |
| acetate, satur. solution | 125 |
| carbonate, satur. solution | 105 |
| phosphate, satur. solution | 106·6 |
| nitrate, satur. solution | 120 |
| Sulphur | 444·4 |
| Sulphuric acid, H_2SO_4 | 326 |
| anhydride α | 15 |
| β | 50 |
| Sulphur dioxide | - 10 |
| Toluene | 111 |
| Xylenes | 136-141 |
| Turpentine, spirits of | 160 |
| Zinc | 916 |

SPECIAL PART

I. RULES FOR SAMPLING.

A.—Fuel.*

Take a shovelful of each wheelbarrow, basket, etc., throw it into a cask or tub. Coarsely grind up the whole without delay, mix the contents, spread them out in a flat, square heap, divide this diagonally into four quadrants, remove two opposite quadrants, grind up the other two more finely and mix them again, and continue in this manner until the weight has been reduced to about $\frac{1}{4}$ cwt. Put this into a tin box, which is soldered up and sent to the testing-laboratory. There this sample is ground again, mixed up, and divided into twelve or sixteen portions in the manner of a chess-board. Take out a teaspoonful from each of these portions and grind them in a porcelain mortar to a powder as fine as dust. This powder is kept in a stoppered bottle, and is well mixed up before taking out a fresh sample for testing.

For separate *moisture tests*, a number of samples are taken during the first sampling, and kept in air-tight vessels.

B.—Ores and Minerals (Pyrites, Manganese, Salt, etc.).

(a) *Smalls, sluck, salt, or other substances not requiring to be crushed.*—Take a sample of about 1 lb. of each weighing-tub, cart, or the like, by means of a scoop, so as to obtain about the same quantity each time. Of railway trucks, which are tipped directly into the warehouse, take three samples, one from the middle and one from each end.† All these single samples are put in a cask and kept covered, to prevent the evaporation of moisture. When the large sample is taken, empty the contents of the cask on a level, clean, and hard place, spread it flat, heap it up in a cone at the centre by going regularly round with a spade; spread this heap again flat, and take a sample of about a quarter of the mass, by taking out with a spade two strips crossing each other at right angles, and adding a little from the centre of each remaining

* According to the rules laid down for the German Official tests of steam-boilers and steam-engines.

† At some factories very unsatisfactory results have been obtained with this mode of sampling; they prefer that described later on (in b), viz., taking a certain number of entire tubs, barrows, or carts as sample.

quadrant. Treat this reduced sample exactly like the larger one, so that a third sample of about 5 lbs. is obtained. Mix this again thoroughly, and fill it into four (or more) wide-necked bottles of 4 ounces capacity, placed close together on a sheet of paper, so that a portion of each handful gets into each of the four bottles. When these are full, they are at once closed with tight-fitting corks; these are cut off straight above the necks of the bottles and well covered with sealing wax, putting on the seals of both buyer and seller, or any other party concerned. The mixing and filling must be done as quickly as possible, in order to prevent the evaporation, or, on the other hand, the absorption of appreciable quantities of moisture during the operation.

The above sample bottles are handed over to the laboratory chemist, who has to pulverise their contents till they pass *completely* through a sieve with holes 1 mm. ($= \frac{1}{25}$ in.) wide; no coarse material must be left behind. From this, after thorough mixing, a smaller sample is taken and reduced to the degree of division necessary for analysis, by grinding in a steel or agate mortar, in the case of softer substances in a porcelain mortar. Manganese samples should not be treated in iron mortars. Moisture is estimated in an unground portion of the sample.

(b) *Ores in pieces requiring to be crushed.*—Large-sized samples must be taken if the lumps of the ore are very coarse. If the pieces are not above the size of an apple, and not too unequal, it is sufficient to take a sample from each tub, etc., as in (a), but with a shovel or scoop holding about 10 lbs. In the case of larger lumps, and of very unequal sizes, it is preferable to tip every tenth or twentieth tub or cart into a separate place, where the whole average sample is collected. In any case, the proportion between the large and small pieces must be represented as accurately as possible in the average sample. This is then crushed to the size of a walnut, either by hand or by machinery, leaving no larger lumps behind. The crushed material is thoroughly mixed by turning it over with a spade several times; it is then spread out in a flat heap and a smaller sample of about $\frac{1}{4}$ cwt. is taken, by lifting out two strips crossing each other at right angles, adding something from the centre of each remaining quadrant. The reduced sample is crushed further, either in a large metal mortar, or preferably with a sledge hammer on a flanged cast-iron plate about 3 ft. square, bedded on a solid foundation; the latter process is much cleaner and more convenient than grinding in a mortar. The coarse portions are sifted out by a riddle of $\frac{1}{4}$ -in. holes and crushed again, till all has passed through. The product is reduced as in (a), by mixing, etc., to a quantity of 2 or 4 lbs., from which the sample bottles are filled as described above.

C.—Chemicals.

Saltcake, soda ash, etc., if in bulk, are sampled as in No. 1, (a). If packed in casks, each third, fifth, or tenth cask, according to the size of the parcel, is bored at one of its bottoms and sampled by means of an *auger* (Fig. 1), which is inserted up to the centre of the cask, turning it round its axis all the while. The single cask samples are put into a large wide-mouthed bottle, as drawn, till the sampling is over. Then empty the whole on to a large sheet of paper, mix thoroughly, crush any lumps with a spatula, and fill



FIG. 1.

the 4-ounce bottles, previously prepared, exactly as described in No. 1 as for ores, observing the simple rules for corking and sealing.

Bleaching powder, potash, and any other substances which are liable to be quickly spoilt in contact with the air by attracting moisture, or from other reasons, are treated like the foregoing substances, but operating with the greatest possible speed, and keeping the large bottles for collecting the cask samples well closed. The sampling is still more safely performed by taking away the upper end of the cask, removing the top layer to a depth of about 2 inches, taking a handful of the material from the interior as far as it is possible to reach in, which should be nearly to the centre of the cask, and placing it in the large bottles. In this

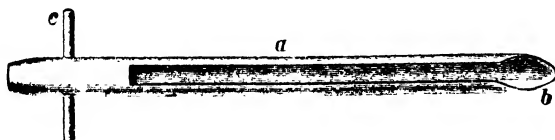


FIG. 2.

way there is the least contact with air. Or else a sample auger is employed, like that shown in Fig. 2. It is made of a piece of gas-pipe of 1½-inch bore, cut open for part of its length, so that a longitudinal slot of 1 inch width, *a*, is formed. One side of the slot is sharpened, as well as the tip *b*, which is driven into the bleaching powder, etc. The upper part of the pipe is left uncut, and is provided with a handle, *c*. Before introducing the auger the cask is well shaken up; then it is placed in an upright position and the auger is driven in as deeply as possible, in case of need by the aid of a hammer. This is done either after opening the cask, or by boring a hole in the end, which is afterwards closed by a piece of tin, with paper underneath. After driving

in the auger, it is turned several times round its axis, so that it cuts through the bleaching powder with its sharp side and is thus filled. The sample drawn out is put on paper, and is crushed as quickly as possible, preferably by means of a small hand-roller; it is then mixed and spread out flat. Small samples are finally taken from various parts by means of a spatula, as quickly as possible, and are put into bottles, which are tightly closed and kept in a dark place. Bleaching powder samples should be always tested with as little delay as possible.

Caustic Soda.—Since the samples absorb moisture and carbonic acid on their surface, even in well-closed bottles, the outer opaque crust must be removed by scraping before weighing out the samples (*cf.* p. 209). It should be borne in mind that the centre of the drum is of weaker strength than the remainder, because the foreign salts accumulate in the portion which remains liquid the longest. The average strength is best represented by the portions next to the bottom and sides of the drum, which solidify quickest. This is most conveniently done while the contents are still in the liquid state. For the control of the manufacture itself it is best to take samples out of every pot during the time its contents are ladled out, from the top, the centre, and the bottom. These are poured out on to a metal plate, where they quickly solidify. The centre sample is the most important one for judging the quality of the pot.

Solid sulphuric anhydride cannot be sampled directly for analysis. An auger cannot be employed, as the mass is too firm and tough; melting the mass in the drums themselves is out of the question, on account of the clouds of fumes. The following process is, therefore, employed:—A large sample of the solid anhydride is mixed with so much exactly analysed “mono-hydrated” sulphuric acid that an acid of about 70 per cent. is formed, which is liquid at ordinary temperatures. This mixture is made in a stoppered bottle, and is gently heated to 30° or 40° C., the stopper being loosely put in until the solution is complete, and a small sample then taken out by means of Lunge and Rey’s glass-tap pipette (p. 172).

II. THE PREPARATION OF STANDARD SOLUTIONS.

As mentioned in the preface, the author has assumed that the user of this handbook is a qualified chemist working in a well-appointed works laboratory. The book is not intended to be used as a students’ text-book, but, in order to prevent misunderstanding as to the units and conventions adopted, some notes regarding standard solutions, indicators, etc., have been included. Fuller particulars, with details of procedure, will be

found in text-books, such as Cumming and Kay's *Quantitative Chemical Analysis*.

Standard Solutions.—Any solution of accurately known composition is called a standard solution.

Normal Solution.—A solution which contains one gram-equivalent of the reacting substance per litre of solution is called a *normal* solution. The gram-equivalent of a substance is the weight of the substance, in grams, which is chemically equivalent to 1.008 g. of hydrogen.

A normal solution of an oxidising agent is one which is capable of yielding 8 g. of "available" oxygen per litre. One litre of a normal solution of an oxidising agent will therefore oxidise 1.008 g. of hydrogen with formation of water.

The Unit of Volume.

The instruments used in volumetric work are graduated in cubic centimetres. The true cubic centimetre is the volume of a cube whose sides are 1 cm. in length. For analytical purposes, it may be taken as equal to the volume of 1 g. of water (as weighed in a vacuum) at 4°.

Measuring instruments are sometimes graduated in terms of Mohr's unit. This unit is often incorrectly called a cubic centimetre, but is actually the volume occupied by a quantity of water (at 15° or 17.5°) which, when weighed in air with brass weights, has an apparent weight of 1 g. This unit (at 15°) is 0.2 per cent. larger than the true cubic centimetre.

RATIO OF WEIGHT TO VOLUME OF WATER, WEIGHED IN AIR WITH BRASS WEIGHTS.

| Temperature. | Weight of 1 c.c. in grams. | Volume in c.c. occupied by 1 gram. | Temperature. | Weight of 1 c.c. in grams. | Volume in c.c. occupied by 1 gram. |
|--------------|----------------------------|------------------------------------|--------------|----------------------------|------------------------------------|
| 10° | 0.9987 | 1.0013 | 21° | 0.9970 | 1.0030 |
| 11° | 86 | 14 | 22° | 67 | 33 |
| 12° | 85 | 15 | 23° | 65 | 35 |
| 13° | 83 | 17 | 24° | 63 | 37 |
| 14° | 82 | 18 | 25° | 60 | 40 |
| 15° | 81 | 19 | 26° | 57 | 43 |
| 16° | 79 | 21 | 27° | 55 | 45 |
| 17° | 77 | 23 | 28° | 52 | 48 |
| 18° | 76 | 24 | 29° | 49 | 51 |
| 19° | 74 | 26 | 30° | 46 | 54 |
| 20° | 72 | 28 | 31° | 43 | 57 |

Measuring instruments, as bought, are often inaccurate. In order to calibrate a vessel, one requires to know

- (1) the weight of water which will occupy 1 c.c. at the given temperature,
- (2) the corrections to be applied for the weight of air displaced by the water and by the brass weights respectively.

In the table on p. 107 these corrections have been introduced.

Use of English Weights and Measures.

The metric system of weights and measures is now almost universally used in analytical work. It is to be regretted, however, that in England it is still usual to specify quantities in the old-fashioned, unscientific English units, *e.g.* grains per gallon or grains per cubic foot.

The analyst is recommended in all such cases to use metric weights and measures, and convert the results by calculation. As there are, however, still laboratories in which the "English system" is used, the following notes may be useful.

The unit of weight of the English system is the grain. All normal solutions are prepared so that 1000 grains by volume (100 decems) contain one equivalent of the reagent in grains, and consequently all normal solutions prepared on the English system are identical in concentration with those prepared on the metric system.

English burettes usually hold 1000 grains, and are divided into 100 parts of 10 grains each, called one decem. The decem corresponds to the cubic centimetre. As, however, this unit, the decem, is ten times the unit of weight, the following rules must be observed when any of the data are to be changed from the metric to the English system :—

Instead of litre read 10,000 grains.

„ cubic centimetre read decem, or ten times the number of grains.

„ grams read ten times the number of grains.

If, for instance, we are told to prepare a standard solution of permanganate by dissolving 15.820 g. of potassium permanganate in 1 litre of water, and that 1 c.c. of such a solution corresponds to 0.028 g. of iron, we obtain a solution of equal strength by dissolving 158.20 grains in 10,000 grains of water, and 1 decem of this solution corresponds to 0.28 grain of metallic iron. The reader should substitute ten times as many grains for the number of grams, ten times as many grains, or an equal number of decems, for the number of cubic centimetres, and 10,000 grains for each litre. Where we are directed to measure out by means of a pipette 50 c.c., we take 500 grains instead, etc.; but when speaking of the number of cubic centimetres on the burette, we substitute exactly the same number of decems.

It will also be useful to remember that :

| | |
|---|--|
| Grams per litre | = grains per 1000 grains. |
| " " | = ounces per 1000 ounces. |
| " " | = ounces per cubic foot (approximately). |
| Grams per litre $\div 16$ | = lbs. per cubic foot. |
| Grams per litre $\times 70$ | = grains per 70,000 grains. |
| " " " | = grains per gallon. |
| $0.4375 \times$ grams per cub. metre | = grains per cubic foot. |
| Kilograms per cubic metre | = lbs. per 1000 lbs. |
| " " " | = lbs. per 16 cubic feet. |
| $\frac{\text{Kilograms per cubic metre}}{16}$ | = lbs. per cubic foot. |
| $16 \times$ cub. metres per kilogram | = cubic feet per lb. |
| Kilograms per square metre | = 0.205 lb. per square foot. |
| Kilograms per sq. metre $\times 4.89$ | = lbs. per square foot. |

As 1 gallon of any dilute aqueous solution weighs approximately 70,000 grains, it is a close approximation to take
Parts per gallon = parts per 70,000.

STANDARD SOLUTIONS IN COMMON USE.

A.—Normal Acid and Alkali.

The only acids in common use as standard acids are sulphuric acid and hydrochloric acid, and of these hydrochloric acid has the wider range of utility. Normal hydrochloric acid has no tendency to lose the free acid but, if exposed to the air, becomes more concentrated.

As standard alkalis, the most useful are sodium hydroxide, sodium carbonate, and barium hydroxide. It is essential that a standard alkali solution should always be used with the indicator used when it was standardised.

Indicators.—The indicators commonly used in acidimetry and alkalimetry are litmus, methyl orange, phenolphthalein, and methyl red.

Indicators for acid and alkali are substances which exhibit a marked change of colour at or near the neutral point. Usually the colour change does not occur at the point of true neutrality and the change occurs at different points with different indicators. This does not affect the accuracy of the results, provided a suitable indicator is used under correct conditions.

Strong Acids and Strong Bases.—If acids and bases are free from carbonates and sulphides, any indicator may be used if the concentration of the standard solution is not less than 0.2 normal. With more dilute solutions, methyl red or phenolphthalein should be used.

Weak Acids with Strong Bases.—Use phenolphthalein.

Weak Bases with Strong Acids.—Use methyl red.

Carbonates and Sulphides with Strong Acids.—This can be

done with cold solutions using methyl orange as indicator. Methyl red or litmus can be used if the titration is carried out at the boiling point of the solution.

For convenience, the above and some further information is given below under the headings of the various indicators.

Litmus.—Although this was at one time the universal indicator, it is nowadays more satisfactory to use other indicators. Litmus is variable in quality and, unless a purified product (azolitmin) is used, the results are often unsatisfactory. It may be used for strong acids and alkalis, but is inaccurate if carbonates are present. It can be used for the estimation of ammonia with a strong acid. It can also be used in the estimation of carbonates, bicarbonates and sulphides if the solution be boiled. Sulphide will bleach the litmus but more litmus can be added towards the end of the titration.

Methyl Orange.—This is the most useful indicator for the titration of carbonates, bicarbonates, sulphides, silicates, borates, and arsenites. If more than traces of carbonate are present, the solution should be boiled when nearing the neutral point and then cooled before completing the titration.

Methyl orange cannot be used for the titration of weak acids. It can be used for titrating ammonia, but methyl red is better.

Phenolphthalein.—This is the most useful indicator for the titration of weak acids, such as acetic acid, with a strong base. It should be used only with strong bases free from carbonate. Organic acids insoluble in water can often be titrated in an alcohol-water solution using this indicator. Phenolphthalein is useless for ammonia or in presence of ammonium salts. With carbonates of the alkalis, it indicates neutrality roughly at the bicarbonate stage.

Methyl Red.—This is the best indicator for the titration of ammonia or solutions containing ammonium salts. It is more sensitive and gives a sharper end-point than methyl orange with very dilute solutions of strong acids and bases. It is useless for weak acids. It is less sensitive than litmus or phenolphthalein to carbonic acid, and the amount present in an ordinary solution of sodium hydroxide does not affect this indicator.

As basis of Alkalimetry and Acidimetry, we employ *chemically pure sodium carbonate*. This is tested for purity by dissolving 5 g. in water, which ought to yield a perfectly clear, colourless solution; if, after acidifying this solution with pure nitric acid, no opalescence is caused by barium chloride, or silver nitrate, the salt may be taken as sufficiently pure. Before using it, the sodium carbonate must be heated in a platinum crucible (or if this is not available a porcelain basin). This is half-filled with the carbonate and is placed on a sand-bath, the sand reaching to the same level outside as the carbonate inside. A thermometer is put in, which at the same time serves as a stirrer. The temperature is raised to 270° to 300° for about half an hour,

with frequent stirring; the contents are then emptied hot into a stoppered weighing-bottle, which is kept in a desiccator up to the time of weighing. Then weigh off, for normal acid, four portions of about 2 g. each into the beakers in which the titration is to take place; for one-fifth normal acid the single portions ought not to exceed 0.4 g. The balance ought to turn to at least 0.2 mg.

As normal acid we prefer *hydrochloric acid*, which has the following advantages over sulphuric and oxalic acid, viz.: 1st, it is more generally applicable, *e.g.*, for alkaline earths; 2nd, its strength, after being fixed by pure sodium carbonate, can be accurately checked by silver nitrate, far more accurately than that of sulphuric acid by barium chloride; 3rd, it does not change on keeping, like oxalic acid.

Normal HCl (36.47 g. HCl per litre) is prepared as follows:—Dilute pure hydrochloric acid to 1.020 specific gravity (4 Tw.). Such an acid will be rather too strong. Fill a burette with this acid, and titrate with it one of the weighed samples of sodium carbonate, the weight of which is w grams. Suppose that x c.c. of this acid are required. As the acid is sure to be too strong, x will always be smaller than $\frac{w}{0.053}$, and we shall have to add to

every x c.c. of the acid $\frac{w}{0.053} - x$ c.c. of water, and if the total quantity of acid of specific gravity 1.020 amounts to V c.c., the amount of water to be added thereto to render it correct will be n c.c., where $n = V \left(\frac{w}{0.053x} - 1 \right)$. For one-fifth normal acid the above factor would be $= \frac{w}{0.0106}$.

If accurate normal alkali is at hand, it may be similarly employed for examining the provisional acid, and then adjusting it to the normal strength.

In any case, the mixed normal acid must be checked by titrating new samples of sodium carbonate, when x ought to be $\frac{w}{0.053}$. A further check is afforded by estimating the chlorine gravimetrically by silver nitrate; 10 c.c. (= 0.3647 HCl) ought to yield 1.4334 g. AgCl.

The ordinary *indicator* in alkalimetry and acidimetry used to be tincture of litmus, which must be kept in open vessels to avoid its being spoiled. When employing litmus, the liquid to be tested must be kept boiling for some time, in order to expel all CO_2 , and normal acid must be added as long as, on further boiling, the colour changes back from red to purple, or blue. This prolonged boiling causes some alkali to be dissolved from most kinds of glass, which makes the tests inaccurate. A test with litmus

rarely lasts less than half an hour, usually more. Phenolphthalein has exactly the same drawbacks. Even the action of the carbon dioxide contained in the air, which comes into contact with the liquid on cooling, may cause trouble in very accurate work. On the other hand, a test is finished in a few minutes, if litmus is replaced by a very dilute solution of *methyl orange*; but in this case the liquids must not be hot, but at the ordinary temperature, and only mineral acids, not oxalic acid, may be employed. The cold solution of sodium carbonate is coloured just perceptibly yellow by adding a drop or two of the solution of methyl orange, preferably by means of a pipette; if the colour is too intense, it will cause the transition into red on neutralisation to be less sharp. CO_2 does not act in the least upon methyl orange; a change of colour only takes place when all Na_2CO_3 has been decomposed. When the Na_2CO_3 has been exactly converted into NaCl , a tinge of brown or red appears in the faintly yellow solution. This is the end-point. Exactly the same course is followed in titrating acids with caustic soda solution; in this case also the reading is taken at the brownish transition colour, before the change to yellow has taken place. The results obtained in this way are identical with those obtained by the *proper* application of litmus or phenolphthalein, that is, working with these indicators under complete exclusion of air, with prolonged boiling, and in porcelain or silver vessels. The great advantage of methyl orange over the last-named indicators is the saving of time, the working at ordinary temperatures, and the possibility of employing glass vessels without any danger of error caused by the use of this material.

Another advantage of methyl orange is that it is not affected by *sulphuretted hydrogen* (which destroys litmus); hence it can be employed, *e.g.*, for the direct titration of black-ash liquors. *Sulphur dioxide* acts upon it like the stronger mineral acids, but only to the extent of one-half of its equivalent; that is, the point of neutrality is reached when the compound NaHSO_3 has been formed. In the presence of *nitrous acid* methyl orange is gradually destroyed, but it is quite easy to employ it even in this case by proceeding as described on p. 162.

It is generally agreed that methyl orange is the best indicator for titrating *bases* by means of strong mineral acids, and this holds good also for the titration of the *strong acids*—sulphuric, hydrochloric, and nitric acid. In these cases, indeed, its advantage over litmus or phenolphthalein is even more marked, because a slight percentage of CO_2 in the standard alkali employed has no effect. But *organic acids* cannot be titrated with methyl orange.

Some authors have proposed, in lieu of methyl orange, the unsulphonated compound, dimethylaminoazobenzene, but this is only soluble in alcohol, and cannot be recommended. This is also the case with ethyl orange.

To prepare *standard alkali*, dissolve about 50 g. of the best commercial caustic soda in 1 litre of pure water and titrate 50 c.c. of this solution with standard acid. More than 50 c.c. of acid will be required; we call this x c.c. The fraction $\frac{5000}{x}$ shows the number of c.c. of the first solution, which must be diluted with pure water to 1 litre in order to obtain a really normal alkali. The solution thus prepared is again checked by titration with normal acid.

The normal alkali, when intended to be used with litmus, should be as free as possible from carbonate, and should be protected against absorption of CO_2 from the air, because otherwise the change of colour does not take place sufficiently rapidly and markedly in cold solutions. A solution of sodium hydroxide *entirely* free from carbonate is difficult to prepare and to preserve when in constant use. When employing methyl orange as an indicator, an ordinary caustic soda solution may be employed without any special precautions. The caustic soda employed should not contain more than a very small proportion of alumina; ordinary strong caustic nearly always fulfils this condition, or it may even be replaced by a solution of 53.00 g. pure sodium carbonate in 1 litre water, which is employed cold, and which yields as accurate results as NaOH , no notice being taken of the CO_2 which escapes with effervescence. The general use of this solution is, however, inconvenient on account of the efflorescence on the burettes, necks of bottles, etc. Weaker (*e.g.*, fifth-normal, or even seminormal) solutions do not have this drawback.

All standard solutions must be prepared and employed as nearly as possible at a certain *temperature*. Mohr prescribes 15° ; some prefer 18°C ., as being more suitable for laboratories. When the solutions have stood for some time in bottles, a little water is evaporated and recondensed in the upper part of the bottles; the contents must then be properly mixed by shaking.

If the temperature of the laboratory differs more than 2° or 3° from that employed for preparing the standard solutions, a correction should be made by means of the following table. In order to reduce the volumes read off at t° to 15° , deduct per 100 c.c. the following amounts :—

| t° | c.c. | t° | c.c. |
|-----------|-------|-----------|-------|
| 15 | 0 | 23 | 0.135 |
| 16 | 0.013 | 24 | 0.156 |
| 17 | 0.027 | 25 | 0.179 |
| 18 | 0.043 | 26 | 0.202 |
| 19 | 0.059 | 27 | 0.227 |
| 20 | 0.076 | 28 | 0.252 |
| 21 | 0.095 | 29 | 0.278 |
| 22 | 0.114 | 30 | 0.305 |

B.—Potassium Permanganate.

The ordinary solution is decinormal, *i.e.*, it yields 0.0008 g. oxygen per c.c. It serves, *e.g.*, for estimating nitrous acid in sulphuric acid, for testing the nitrogen acids in the chamber exits, for testing manganese ore, for testing Weldon mud, etc.

The solution is made by dissolving pure crystallised potassium permanganate, and is then quite stable, if protected from dust and direct sunlight. Dissolve 3.161 g. of pure permanganate in 1 litre of cold water. (Do not heat the solution, and do not grind the crystals.) Keep the solution in a dark place and free from dust. If any sediment forms in the solution at any time, reject it. Store in a bottle with a glass stopper.

None of the methods formerly employed for standardising permanganate (by means of metallic iron, or oxalic acid, or hydrogen peroxide, etc.) is entirely free from objections. No such objection exists to the employment of *pure sodium oxalate*, first proposed by Sorensen. This salt need only be kept for a few hours in a drying oven at 100°, and then allowed to cool in a desiccator over calcium chloride. Dissolve about 0.26 g. of this (exactly weighed) in about 200 c.c. water, heated to 60°–70°, add dilute sulphuric acid, and run in the permanganate solution from a burette, first quickly, then drop by drop, until a permanent red colour is produced. If *a* be the weight of sodium oxalate, *b* the c.c. of permanganate solution used, the fraction $\frac{29.851 a}{b}$ gives the quantity of oxygen given off per c.c. of the permanganate solution.

If a brown precipitate (of MnO_2) should be formed during the titration, the experiment must be rejected, but this occurs only when the solutions are too concentrated or too hot (*i.e.* above 70°).

Permanganate is best employed in a burette with a lateral hollow glass-tap. Any change in its titre (due to dust, etc.) is perceptible by a deposition of MnO_2 in the bottle. It is advisable to check the solution once every three months.

Permanganate can be used with perfect accuracy in the presence of free hydrochloric acid, if the solutions contain a considerable quantity of manganese salts; in other cases the same effect is produced by adding, say 1 g. of manganese sulphate free from iron.

C.—Iodine.

Weigh exactly 12.692 g. of pure resublimed iodine (either bought as such, or prepared by grinding up commercial iodine with 10 per cent. of potassium iodide and resubliming) on a balance turning at least with 1 mg.; put it into a litre flask containing a concentrated solution of 15 to 18 g. KI, close the flask,

agitate till the iodine is completely dissolved, and fill up to the mark. This decinormal solution is checked by the arsenite solution (p. 115). Both solutions ought to be precisely equivalent, c.c. per c.c.

For estimating very small quantities of sodium sulphide a special iodine solution is sometimes made, by dissolving 3.2515 g. of pure iodine with 5 g. of potassium iodide in a litre, to correspond to 0.001 g. Na_2S per c.c.

Solutions of iodine, especially the more dilute ones, keep a long time in well-stoppered bottles in a cool place, but they ought to be checked once a month by the arsenite solution.

Preparation of the Starch Solution.—Grind up 3 g. potato starch with a little water to a homogeneous paste; introduce this gradually into 300 g. of boiling water, contained in a porcelain dish, and continue the boiling till an almost clear liquid has been produced. Allow this to settle in a tall beaker, pour the clear portion through a filter, and saturate it with common salt. This solution, when kept in a cool place, is stable for some time; as soon as fungoid growths are noticed in it, it is thrown away.

A very convenient form of soluble starch is that made by Zulkowsky's method, by heating 100 parts of concentrated glycerine with 6 parts of starch to 190°C . for about an hour, pouring into water, precipitating the soluble starch by alcohol, and filtering. This starch is kept in the state of a thick paste, not allowed to dry, and a small quantity is taken out for each test by means of a glass rod. There are also other forms of soluble starch, e.g., "ozone-starch."

D.—Sodium Arsenite.

This serves for standardising the iodine solution, and as its volumetrical complement, especially in testing bleaching powder. Employ commercial pure powdered arsenious acid: test its purity by subliming a little from a small dish into a watch-glass, when no yellow sublimate of As_2S_3 (which volatilises more easily than As_2O_3) should result initially; on heating more strongly it should leave no residue. Before use the powdered As_2O_3 is kept for some time over sulphuric acid in a desiccator, and can then be weighed out without any special precautions, since it is not hygroscopic. For preparing a decinormal solution, weigh out exactly 4.948 g. As_2O_3 , dissolve it in a little hot solution of caustic soda, neutralise with dilute sulphuric acid (using phenolphthalein as indicator), add a solution of about 20 g. sodium bicarbonate in 500 c.c. water, and dilute on cooling to 1000 c.c. This solution is quite stable, and equivalent to 0.003546 g. chlorine or 0.012692 g. iodine per c.c.

If really pure and dry arsenious acid has been employed, the above solution will be correct at once. But when preparing large

quantities, it ought to be checked by grinding up 0.5 g. iodine with 0.1 g. potassium iodide, heating this mixture in a small dish on a sand-bath or upon an asbestos board till abundant vapours arise, covering with a dry watch-glass, allowing the major portion, but not the whole, of the iodine to sublime into the watch-glass, covering this with a second watch-glass which fits air-tight upon the former, and has been weighed with it, and weighing. Slip the watch-glasses into a solution of 1 g. of potassium iodide (free from iodate), in 10 g. water, wait a little till the iodine is dissolved, dilute with 100 c.c. water, and titrate with the arsenite solution. When the colour is only a light yellow, add a little starch solution, and titrate exactly till the blue colour has just vanished. The c.c., of arsenite solution used, multiplied by 0.012692, ought to correspond exactly with the weight of iodine taken. Or the dry, sublimed iodine is transferred directly from the upper watch-glass into a tared stoppered weighing-bottle, weighed, and dissolved in KI solution in the same bottle.

E.—Silver Nitrate.

Weigh out exactly 16.989 g. of pure crystallised silver nitrate, preferably kept in a desiccator for a few hours, and dissolve in 1 litre. This gives a decinormal solution, corresponding per c.c. to 0.003546 g. Cl, or 0.003647 g. HCl, or 0.005846 g. NaCl. By dissolving 2.906 g. AgNO_3 in 1 litre, a solution is obtained corresponding to 0.001 g. NaCl per c.c.

Ammoniacal silver solution, for Lestelle's estimation of alkaline sulphides, is obtained by dissolving 13.818 g. of pure silver in pure nitric acid, adding 250 c.c. of ammonia, and diluting to 1 litre. Each c.c. of this corresponds to 0.005 g. Na_2S .

F. —Copper Sulphate.

Copper solution, for testing ferrocyanide, is obtained by dissolving 12.486 g. pure crystallised, non-effloresced, cupric sulphate, in 1 litre water.

G.—Oxalic Acid.

Oxalic acid solution is employed for testing the "base" of Weldon mud, and caustic soda or lime in the presence of carbonate.

Dissolve 63.03 g. pure, non-effloresced, crystallised oxalic acid in 1 litre water, and check with normal alkali. This solution is not quite stable, especially when exposed to daylight; nor can it be employed for alkalimetry, when using methyl orange as an indicator.

III. FUEL AND FURNACES.

A.—Fuel.

The following tests should be applied in the case of lignite, peat, coal, and coke. The method of sampling is described on p. 103.

1. *Moisture*.—Heat 100 to 200 g. of coal to 110° (not above), for two hours, preventing access of air as much as possible. At a higher temperature the result might be too high, owing to escape of volatile matters, or too low, owing to a partial oxidation. The sample should be broken up quickly into pieces not smaller than a bean, otherwise too much water would evaporate during the process. Lignite and peat are heated to 100° for five or six hours, and repeatedly weighed, till no further diminution of weight takes place. Coke is heated to 110° for two hours.

All other tests are made with *air-dried* material. The average sample is weighed before taking the samples for the tests; it is then spread out in a thin layer and allowed to lie in ordinary dry air for forty-eight hours. It is then weighed again, and the results obtained with such air-dried fuel are calculated on the original (undried) material.

2. *Residual Coke (Fixed Carbon)*.—One g. of finely powdered coal is placed in a platinum crucible at least 1½ in. deep, weighing from 20 to 30 g., provided with a tightly fitting cover. The crucible should then be heated by means of an ordinary Bunsen burner, the flame of which should not be less than 7 in. high. The crucible should be supported on a triangle of thin platinum wire, and it should be so placed that the space between the bottom of the crucible and the top of the burner is 2½ to 3 in. The heating ought not to last longer than a few minutes, but must be continued as long as any appreciable quantity of inflammable matter escapes. The surface of the crucible cover should then be clean, but its lower side should be covered with carbon. If the flame be smaller, or the crucible be supported by a stout wire triangle, the yield of coke will be too high. The results should always be calculated upon coal or coke free from ash, in order to render them comparative. Good coal for reverberatory furnaces should yield from 60 to 70 per cent. of coke.

3. *Ash*.—This estimation is very simple for lignite or peat; coke requires a very high temperature; coal which cakes presents most difficulty. This type of coal must be powdered very finely, and heated up gradually, so that the volatile matters may escape before the powder can form a cake. If an analysis is only occasionally required, 2 to 5 g. of finely ground coal is heated in a platinum crucible, which is fitted in a hole into a stoneware

slab, or, better, in a fused-silica plate (Fig. 3). This is placed in a slanting position on a tripod stand. The slab serves to separate the air required for oxidation from the gases of the burner, and greatly hastens the combustion, which is thus completed in two hours, whereas without the slab it frequently remains incomplete even after eight or ten hours' heating. It is not advisable to use a blowpipe, because the chance of mechanical loss is thereby greatly increased. If determinations have to be made frequently, it is preferable to effect the combustion in a muffle furnace, or still more quickly in a platinum boat placed in a heated porcelain tube, through which a current of oxygen is passed. When using the latter, the coal or coke should be broken into small pieces, and not ground fine, or else the oxygen does not come sufficiently into contact with the lower strata.

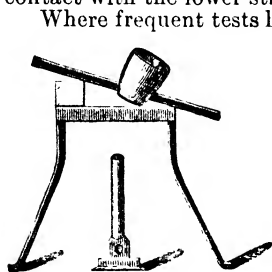


FIG. 3.

Where frequent tests have to be made, several platinum dishes can be placed in a muffle at the same time. It is best to cover the dishes or boats at first by a mica plate and to remove this only when the gases have been driven off, after which the ignition is continued, until no more black spots are visible and the weight remains constant.

4. *Sulphur* (Eschka's method).—

Mix 0.5 to 1 g. of the finely ground coal with $1\frac{1}{2}$ times its weight of an intimate mixture of 2 parts of well-burnt magnesia and 1 part of anhydrous

sodium carbonate. The magnesia and sodium carbonate should be tested for traces of sulphate before use, and only pure reagents used. The mixture is made in a platinum crucible by means of a glass rod, and the crucible, without putting on the cover, is heated in an inclined position, in such manner that only its lower portion attains a red heat. This is most conveniently done by placing it in a fused silica plate, provided with a hole, as shown in Fig. 3. The combustion of the sulphides to sulphates should be promoted by frequent stirring with a thick platinum wire; it will be finished in about an hour, during which time the grey colour of the mixture mostly passes into yellow, red, or brown. The calcined mass is covered with hot water, and bromine water is added until the liquid shows a slight yellow colour. Then heat the whole to boiling, decant the liquid through a filter, and wash the residue with hot water. Add hydrochloric acid to the aqueous solution, boil till all the bromine has been removed and the liquid has been decolorised, and add a solution of barium chloride, drop by drop, always at a boiling heat, until the precipitation is complete.

Even if the gas employed for heating the crucible should

contain a notable quantity of sulphur, no error is caused if the products of combustion are kept away from the contents of the crucible by the silica shield as shown in the figure. One part BaSO_4 indicates 0.1374 part S.

5. *The calorific power* of fuel can be estimated by ascertaining the percentage of carbon and hydrogen, according to the ordinary methods of elementary analysis, and calculating the results according to Dulong's formula. In the case of coal it is necessary to take account of the volatile sulphur—that is, that which is determined by heating in a current of oxygen, passing the gases through neutralised hydrogen peroxide, and titrating the sulphuric acid formed. If the percentage of C, H, and (volatile) S, and that of the moisture (W), is known, the percentage of the oxygen is expressed by the equation:—

$$\text{O} = 100 - (\text{C} + \text{H} + \text{S} + \text{W} + \text{ash}).$$

The nitrogen contained in the coal may be neglected. The calorific power of the coal, expressed in gram-calories, is then

$$= 81 \text{ C} + 290 \left(\text{H} - \frac{\text{O}}{8} \right) + 25 \text{ S} - 6 \text{ W}.$$

A direct estimation of the heating power of fuel can be made by means of the calorimetric bomb, of which a description is given in *Tech. Meth.*, vol. i., p. 340 (second edition).

B.—Furnaces.

1. *Chimney Gases.*—In these, CO_2 , O, CO, and N (the latter by difference) are most conveniently estimated by the Orsat apparatus, shown in Fig. 4. This consists of a gas-burette, A, connected with the water-filled level-bottle, B, by means of a rubber tube. A is filled to the zero point with water, and by lowering B gas is aspirated, either from the supply tube C or from the absorption pipettes, D, E, F. The gas is forced into each of these pipettes by opening its special tap and raising B. For reading the volume of gas in A, the bottle B must be held in such a position that the level of water is the same in A and B.

The absorption pipettes are charged as follows:—Tube D receives 110 c.c. of caustic potash solution of specific gravity 1.20 to 1.28. This absorbs CO_2 , and can serve for a long time. Tube E serves for absorbing the oxygen by means of very thin sticks of phosphorus, kept under water. This tube, when not in use, should be protected from the light by a covering of black paper. Any tarry matters getting into this tube render the phosphorus inactive, and must therefore be kept out by filtering the gas before entering into C, through asbestos, cotton-wool, or other suitable

material. The absorption of the oxygen by the phosphorus only sets in at 16°C ., better at 18°C . In case the room is at a lower temperature, the vessel E must be cautiously warmed up by a spirit-lamp. In tube F the carbon monoxide is absorbed. For this purpose a solution is prepared by shaking up in a closed bottle 250 g. cuprous chloride with a solution of 250 g. ammonium chloride in 750 c.c. water. When completed, a spiral of copper wire, reaching from top to bottom, is introduced into

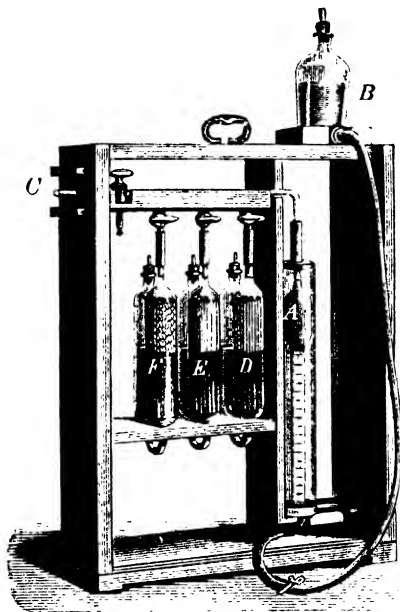


FIG. 4.

the stock bottle. This bottle is always kept well closed when not in use. Before charging tube F, 3 vols. of the solution from the stock bottle are mixed with 1 vol. ammonia, specific gravity 0.905. One c.c. of this mixture ought to absorb 16 c.cm. CO, but this requires prolonged shaking. The reagent in F must be frequently renewed; if this is neglected, it may even yield up some CO to gases containing too little of it. The reagent in F also absorbs ethylene, but this gas does not occur in chimney gases. Since the solution in F also absorbs oxygen, the latter must always be removed before employing pipette F.

For daily use it is often sufficient to test merely for CO_2 , by means of the caustic potash solution in pipette D.

For the testing of acidity in flue gases, see p. 142.

Checking the Working of Furnaces.—The estimation of CO_2 in the chimney gases, if combined with an observation of temperature, checks both the efficiency of a furnace or boiler and the daily work of the firemen, according to a formula worked out by Lunge (*Zsch. f. angew. Chem.*, 1889, p. 240). A consecutive number, say from 10 to 15 tests for CO_2 , are made by an Orsat apparatus in the flue leading from the furnace to the chimney, and the mean volume percentage of CO_2 found is called n . At the same time, a thermometer with very long stem, tightly inserted in the testing hole in such manner that its bulb is well within the flue, but with the scale outside, is observed at frequent intervals, and the mean temperature of the gases is called t' , that of the air outside t . c is the specific heat of a cubic metre of CO_2 , expressed in gram-calories; c' that of N or O (see below). The total volume of exit gases produced by the combustion of 1 kg. of carbon burnt on the grate is $= 1.854 + 1.854 \left(\frac{100}{n} n \right)$ cubic metres, and the loss of heat in the exit gases, expressed in gram-calories:—

$$L = 1.854 (t' - t) c + 1.854 (t' - t) \left(\frac{100}{n} n \right) c'.$$

The loss, expressed in per cent. of the heat theoretically given out by the carbon, is:—

$$\frac{100 L}{8080}$$

The value of c' may be assumed for all temperatures $= 0.31$; that of c varies with the temperature, and must be taken as follows:—

| | | |
|------------------|----------|--------------|
| If t' is below | 150° C., | $c = 0.41$. |
| „ between | 150-200° | $= 0.43$. |
| „ „ | 200-250° | $= 0.44$. |
| „ „ | 250-300° | $= 0.45$. |
| „ „ | 300-350° | $= 0.46$. |

Note.—The observations of n and t' must be made several times in succession, and the average value taken as final. For accurate investigations several series of tests must be made at different times of the day.

Instruments have been devised for a continuous approximate check of the percentage of CO_2 in chimney gases, such as Arndt's Oeconometer.

2. *Gas from Producers (Generators).*—In producer gas usually only CO_2 and CO are estimated by means of Orsat's apparatus, as described, p. 120. Any ethylene present in the producer gas would

be absorbed and estimated together with the CO . *Hydrogen* can be estimated in the residue from absorbing CO_2 , CO , C_2H_4 , and O , by mixing it with a measured volume of air, and passing the mixture over gently heated platinum or palladium asbestos.* The estimation is conveniently done in Lunge's modification of Orsat's apparatus, Fig. 5. The indicating letters correspond to those in Fig. 4, but there is an additional U-tube, G, connected

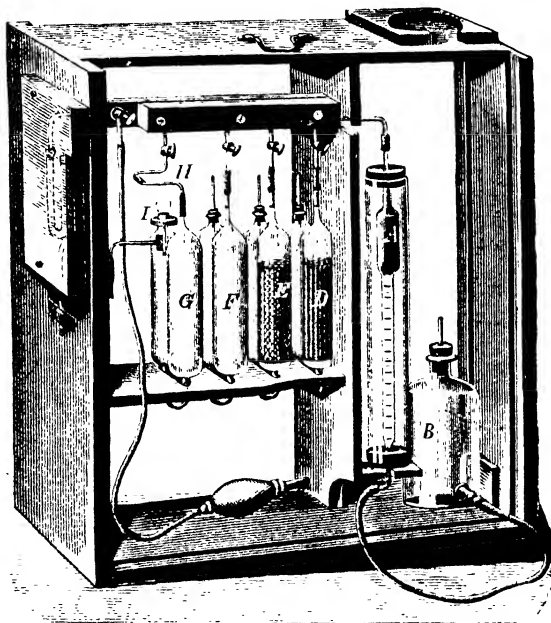


FIG. 5.

with a capillary, H, of refractory glass. H contains platinum or palladium asbestos and can be heated by the small spirit lamp, I, turning on a pivot. The U-tube G is filled with water. The gas freed from CO_2 , CO , C_2H_4 , and O (if this be present) is mixed in the gas-burette A with as much air as the space will allow, and

* This can be obtained ready-made or is prepared by soaking a few threads of long soft asbestos in a strong solution of platinum or palladium chloride, mixed with a saturated solution of sodium formate and enough sodium carbonate to produce an alkaline reaction. After an hour's soaking the asbestos is dried completely in a water-bath, whereby the metal is precipitated in a very minute state of division. The soluble salts are then washed out by hot water and the asbestos is again dried.

a reading is taken. This air will suffice for a quantity of hydrogen corresponding to $\frac{1}{10}$ of the employed volume of air (*i.e.*, twice the volume of oxygen contained in that air). If more H be present, which will only occur in the case of "water gas," either less than 100 c.c. of gas must be employed at the commencement for the analysis, or the residual gas is mixed with oxygen instead of with air. The capillary tube H is heated very gently by means of the lamp I, and the gaseous mixture is quickly passed once through it into G and back again, when one end of the platinum asbestos should become red hot. The residual gas is again measured and $\frac{2}{3}$ of the diminution in volume calculated as hydrogen. If methane (marsh gas, CH_4) is to be estimated, the residue from the last operation is mixed with more air and burnt by means of

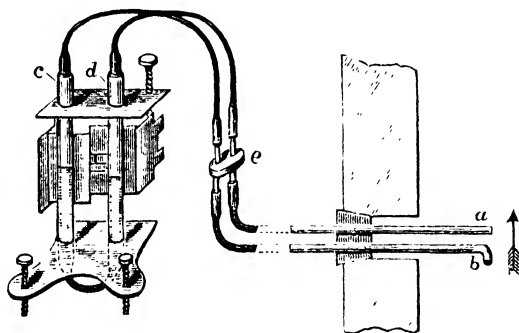


FIG. 6.



FIG. 7.

an electrically heated palladium or platinum wire, enclosed in a capillary tube. If a capillary platinum tube is employed, filled with a few platinum wires, so as to leave a very small space for the gases to pass through, the electric heating may be replaced by that of a broad gas flame, producing a strong red heat.

3. *Speed of Draught.*—A convenient apparatus for measuring this in chemical works, where any fine mechanism would soon be ruined, is Fletcher's anemometer, based upon the movement of a column of ether in a U-tube (described in Lunge-Cumming's *Acid and Alkali*, vol. ii., p. 136). Fig. 6 shows this in the simpler form, leaving out the microscopes, which are quite unnecessary for reading the divisions of the scale or the vernier. The ends of the glass tubes *a b* should be placed rather less than one-sixth of the diameter of the flue from its inner wall. The straight end of *a* ought to be as exactly parallel as possible to the

direction of the draughts; the end of *b* ought to be exactly at a right angle to this, so that the current blows straight into it. Without this precaution a mistake is made, which is avoided by the arrangement shown in Fig. 7, and proposed by Hurter, viz., employing tubes with ends bent in opposite directions. The tubes *a b* communicate with the ether tube *c d*; the draught causes the ether to rise in *a* by aspiration and to fall in *b* by the pressure of the air blowing into the tube. The difference of level between *c* and *d* is read off by means of the scale and vernier. The sliding disc *e* is then turned through 180°, whereby the currents are reversed. There will now be a difference of levels in the opposite direction, but equal in amount to the first, if the observation is correct. The sum of these two differences is the "anemometer reading" given in the tables.

The following tables show the application of the readings of the Anemometer for calculating the speed of draughts, both for instruments graduated on the inch scale and for those on the metrical scale.

a.—TABLE TO SHOW THE SPEED OF CURRENTS OF AIR.

At a temperature of 15° C. = 60° F.; Barometer, 760 mm. = 29·92 inches.

A.—Readings in Inches.

| Anemometer Reading. Inches. | Speed. Feet per Second. | Anemometer Reading. Inches. | Speed. Feet per Second. | Anemometer Reading. Inches. | Speed Feet per Second. | Anemometer Reading. Inches. | Speed. Feet per Second. |
|-----------------------------|-------------------------|-----------------------------|-------------------------|-----------------------------|------------------------|-----------------------------|-------------------------|
| ·01 | 2·855 | ·16 | 11·42 | ·32 | 16·15 | ·95 | 27·83 |
| ·02 | 4·038 | ·17 | 11·77 | ·34 | 16·65 | 1·00 | 28·55 |
| ·03 | 4·945 | ·18 | 12·11 | ·36 | 17·13 | 1·25 | 31·93 |
| ·04 | 5·710 | ·19 | 12·45 | ·38 | 17·60 | 1·50 | 34·97 |
| ·05 | 6·384 | ·20 | 12·77 | ·40 | 18·06 | 1·75 | 37·77 |
| ·06 | 6·993 | ·21 | 13·08 | ·45 | 19·15 | 2·00 | 40·37 |
| ·07 | 7·554 | ·22 | 13·39 | ·50 | 20·18 | ... | ... |
| ·08 | 8·075 | ·23 | 13·70 | ·55 | 21·17 | ... | ... |
| ·09 | 8·565 | ·24 | 13·99 | ·60 | 22·12 | ... | ... |
| ·10 | 9·028 | ·25 | 14·28 | ·65 | 23·02 | ... | ... |
| ·11 | 0·469 | ·26 | 14·56 | ·70 | 23·89 | ... | ... |
| ·12 | 9·891 | ·27 | 14·84 | ·75 | 24·73 | ... | ... |
| ·13 | 10·29 | ·28 | 15·11 | ·80 | 25·54 | ... | ... |
| ·14 | 10·68 | ·29 | 15·38 | ·85 | 26·32 | ... | ... |
| ·15 | 11·06 | ·30 | 15·64 | ·90 | 27·08 | ... | ... |

B.—Readings in Millimetres.

| Read- ing. | Speed. | Read- ing. | Speed. | Read- ing. | Speed. | Read- ing. | Speed. | Read- ing. | Speed. | Read- ing. | Speed. |
|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|
| mm. | m. | mm. | m. | mm. | m. | mm. | m. | mm. | m. | mm. | m. |
| 0.1 | 0.575 | 1.4 | 2.040 | 2.7 | 2.883 | 5.0 | 3.855 | 10.0 | 5.452 | 19.0 | 7.515 |
| 0.2 | 0.771 | 1.5 | 2.111 | 2.8 | 2.885 | 5.2 | 3.931 | 10.5 | 5.586 | 20.0 | 7.710 |
| 0.3 | 0.944 | 1.6 | 2.181 | 2.9 | 2.985 | 5.4 | 4.006 | 11.0 | 5.718 | 21 | 7.900 |
| 0.4 | 1.090 | 1.7 | 2.248 | 3.0 | 2.986 | 5.6 | 4.080 | 11.5 | 5.846 | 22 | 8.086 |
| 0.5 | 1.205 | 1.8 | 2.313 | 3.2 | 3.077 | 5.8 | 4.152 | 12.0 | 5.972 | 23 | 8.268 |
| 0.6 | 1.341 | 1.9 | 2.370 | 3.4 | 3.179 | 6.0 | 4.223 | 12.5 | 6.095 | 24 | 8.446 |
| 0.7 | 1.442 | 2.0 | 2.438 | 3.6 | 3.271 | 6.5 | 4.395 | 13.0 | 6.216 | 25 | 8.620 |
| 0.8 | 1.560 | 2.1 | 2.498 | 3.8 | 3.361 | 7.0 | 4.561 | 13.5 | 6.334 | 36 | 9.448 |
| 0.9 | 1.686 | 2.2 | 2.557 | 4.0 | 3.448 | 7.5 | 4.721 | 14.0 | 6.450 | 35 | 10.199 |
| 1.0 | 1.724 | 2.3 | 2.615 | 4.2 | 3.460 | 8.0 | 4.876 | 15.0 | 6.667 | 40 | 10.903 |
| 1.1 | 1.808 | 2.4 | 2.671 | 4.4 | 3.616 | 8.5 | 5.026 | 16.0 | 6.896 | 45 | 11.565 |
| 1.2 | 1.889 | 2.5 | 2.726 | 4.6 | 3.698 | 9.0 | 5.172 | 17.0 | 7.108 | 50 | 12.190 |
| 1.3 | 1.966 | 2.6 | 2.779 | 4.8 | 3.777 | 9.5 | 5.314 | 18.0 | 7.314 | | |

β.—CORRECTIONS FOR TEMPERATURE.

Column *a* shows the temperature of the chimney or flue, column *b* the factor for multiplying the figure found in Table *a* in order to arrive at the real speed of the current of gas.

A.—Readings in Degrees Fahrenheit.

| Fahr. <i>a.</i> | <i>b.</i> | <i>a.</i> | <i>b.</i> | <i>a.</i> | <i>b.</i> | <i>a.</i> | <i>b.</i> |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 0 | 1.0634 | 90 | 0.9723 | 180 | 0.9012 | 380 | 0.7865 |
| 5 | 1.0577 | 95 | 0.9679 | 185 | 0.8977 | 400 | 0.7763 |
| 10 | 1.0520 | 100 | 0.9636 | 190 | 0.8943 | 425 | 0.7663 |
| 15 | 1.0464 | 105 | 0.9593 | 195 | 0.8909 | 450 | 0.7556 |
| 20 | 1.0409 | 110 | 0.9551 | 200 | 0.8875 | 475 | 0.7454 |
| 25 | 1.0355 | 115 | 0.9509 | 210 | 0.8808 | 500 | 0.7356 |
| 30 | 1.0302 | 120 | 0.9468 | 220 | 0.8743 | 525 | 0.7261 |
| 35 | 1.0250 | 125 | 0.9428 | 230 | 0.8680 | 550 | 0.7171 |
| 40 | 1.0198 | 130 | 0.9388 | 240 | 0.8614 | 575 | 0.7085 |
| 45 | 1.0148 | 135 | 0.9348 | 250 | 0.8557 | 600 | 0.7000 |
| 50 | 1.0098 | 140 | 0.9309 | 260 | 0.8497 | 650 | 0.6841 |
| 55 | 1.0049 | 145 | 0.9270 | 270 | 0.8438 | 700 | 0.6691 |
| 60 | 1.0000 | 150 | 0.9232 | 280 | 0.8380 | 750 | 0.6552 |
| 65 | 0.9952 | 155 | 0.9194 | 290 | 0.8324 | 800 | 0.6420 |
| 70 | 0.9905 | 160 | 0.9156 | 300 | 0.8269 | 850 | 0.6297 |
| 75 | 0.9858 | 165 | 0.9119 | 320 | 0.8163 | 900 | 0.6181 |
| 80 | 0.9812 | 170 | 0.9083 | 340 | 0.8060 | 950 | 0.6070 |
| 85 | 0.9767 | 175 | 0.9047 | 360 | 0.7960 | 1000 | 0.5964 |

B.—Readings in Degrees Centigrade.

| a. ° C. | b. | a. ° C. | b. | a. ° C. | b. | a. ° C. | b. | a. ° C. | b. | a. ° C. | b. |
|------------|-------|------------|-------|------------|-------|------------|-------|------------|-------|------------|-------|
| 10 | 1.046 | 18 | 0.995 | 42 | 0.956 | 66 | 0.922 | 140 | 0.885 | 260 | 0.785 |
| 5 | 1.036 | 20 | 0.991 | 44 | 0.953 | 68 | 0.919 | 150 | 0.825 | 270 | 0.728 |
| 0 | 1.027 | 22 | 0.988 | 46 | 0.950 | 70 | 0.916 | 160 | 0.815 | 280 | 0.721 |
| 2 | 1.023 | 24 | 0.985 | 48 | 0.947 | 75 | 0.909 | 170 | 0.806 | 290 | 0.715 |
| 4 | 1.020 | 26 | 0.981 | 50 | 0.944 | 80 | 0.903 | 180 | 0.797 | 300 | 0.709 |
| 6 | 1.016 | 28 | 0.978 | 52 | 0.941 | 85 | 0.897 | 190 | 0.788 | 320 | 0.697 |
| 8 | 1.012 | 30 | 0.975 | 54 | 0.938 | 90 | 0.890 | 200 | 0.780 | 340 | 0.685 |
| 10 | 1.009 | 32 | 0.972 | 56 | 0.935 | 95 | 0.884 | 210 | 0.772 | 360 | 0.676 |
| 12 | 1.005 | 34 | 0.968 | 58 | 0.933 | 100 | 0.878 | 220 | 0.764 | 400 | 0.654 |
| 14 | 1.003 | 36 | 0.965 | 60 | 0.930 | 110 | 0.867 | 230 | 0.756 | 450 | 0.631 |
| 15 | 1.000 | 38 | 0.962 | 62 | 0.927 | 120 | 0.856 | 240 | 0.749 | 500 | 0.608 |
| 16 | 0.998 | 40 | 0.959 | 64 | 0.924 | 130 | 0.845 | 250 | 0.742 | | |

A very simple and cheaper instrument is Seger's Differential Anemometer, Fig. 8. The U-tube A is surmounted by two enlargements, B and C. D is a sliding scale, adjustable by slits *a a* and screw-pins *b b*. The tube is filled with two non-miscible liquids of nearly equal specific gravity; for instance, paraffin oil and dilute spirits of wine (coloured). The line of contact, at X, is the zero point of the scale D. If an aspirating force is acting on the surface of the liquid in C, the level of the liquid will be raised in C, and the point X will be lowered in a multiplied ratio, corresponding to the difference in the sectional areas of the narrow part of A and the enlargements in C, say 1 : 20.

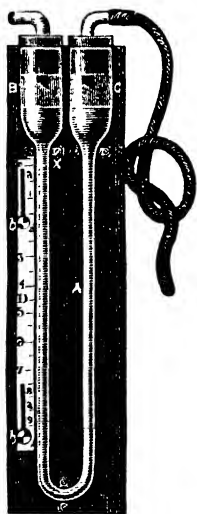


FIG. 8.

C. Temperature.

The measurement of temperatures up to about 300° calls for no special remark, as the ordinary mercurial thermometers are always used. For higher temperatures a large number of *pyrometers* have been constructed. All of these are unreliable after prolonged use, many of them even from the very beginning, and they require a frequent control of their indications by calorimetric methods. Among these "empirical" pyrometers those mostly used are: Gauntlett's (up to 900° C. or 1600° F.), Steinle and Hartung's graphite pyrometer (up to 1200° C.), and Klinghammer's

Thalpotasimeter. In many cases Prinsep's metallic alloys, of definite fusing points, and Seger's cones, do good service; the fusing points corresponding to the commercial forms of the Seger cones have been given on p. 61.

The calorimetric control can be effected by any of the well-known calorimeters, such as Mahler's or Fischer's, but is a somewhat difficult and complicated operation, and the working of the air pyrometer is even more so.

Most of the drawbacks formerly connected with pyrometry have been removed by the construction of Le Chatelier's *Thermo-electric Pyrometer*. Its working part is shown in Fig. 9. It consists of a thermocouple, composed of a wire *a* of pure platinum, and a wire *b* of an alloy of 90 parts of platinum+10 parts of rhodium, soldered to the former. These wires are insulated by

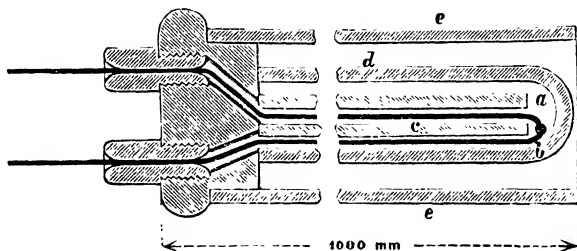


FIG. 9.

porcelain tubes *c*, *d*, about 3 feet long, and protected on the outside, against heating gases, by the iron pipe *e*. The wires are connected with platinum or copper wires, leading to a galvanometer, and the indications of the needle of the latter show the temperature at the point where *a* and *b* are soldered together. The temperature scale marked on the galvanometer is fixed by comparing it with an air pyrometer at the works where the instruments are made.

The following rules must be observed for the use of this pyrometer. The galvanometer should be placed in a horizontal position and so as to be protected against mechanical oscillations, preferably on a wall-bracket, and this may be at some distance from the pyrometer itself—*e.g.* in the manager's office. Before moving the galvanometer from its place, the needle should be always arrested. After fixing it on its bracket, the arresting-screw is cautiously loosened, until the needle begins to move. If it does not point to zero after being placed in a horizontal position, this must be effected by moving the adjusting screws. The electric resistance of the conducting wire should not appreciably exceed 1 ohm; up to distances of about 300 feet this will be

attained by employing insulated copper wire of $\frac{1}{16}$ -inch thickness. The junction of the couple with the conducting wires ought not to be much above the ordinary temperature. If one of the wires should break, the contact can be re-established by twisting the ends tightly together for a length of about $\frac{1}{2}$ inch; it is preferable to fuse them together in an oxyhydrogen flame. If the temperature within the furnace does not exceed 1000° , the pyrometer may be left permanently inside; for higher temperatures, which would cause the iron pipe to soften and to burn away too rapidly, the pyrometer should be taken out and introduced merely for taking an observation, which may be done ten minutes afterwards. Even then it is best to provide a fireclay slab on which the instrument can rest. Le Chatelier's pyrometer may be employed for temperatures up to 1500° C. For higher temperatures, up to 2100° , W. C. Heraeus (Hanau, Germany) has constructed a thermocouple, consisting of a wire of pure iridium, fused to another wire of an alloy of 90 parts iridium + 10 ruthenium.

For such high temperatures Wanner's pyrometer is now frequently used. It allows a photometric comparison of the polarised light from a small electric lamp with that of the furnace, etc., to be tested, by means of an instrument like a telescope; it is easy to handle, and is serviceable for approximately measuring temperatures above 1500° , where Le Chatelier's pyrometer cannot be employed. It is also more convenient than the latter for estimating temperatures inside the furnace at some distance from the front of the furnaces. (Supplied by Townson & Mercer, London.)

D.—Feed-Water for Steam-Boilers, etc.

1. *Hardness*.—The English degrees of hardness are based on the unit of 1 part CaCO_3 , or its equivalent of MgCO_3 , in 70,000 parts of water (grains to the gallon). The French degrees signify each 1 part CaCO_3 (or MgCO_3) in 100,000 water, the German degrees that of 1 part CaO (or MgO) in 100,000 water.

The testing for hardness was formerly mostly effected by Clark's soap test. The methods to be described here are both simpler and more accurate than the soap test.

(a) *Temporary Hardness* (alkalinity) is that which is removed by prolonged boiling, by which operation nearly all the CaCO_3 and some of the MgCO_3 is precipitated. This can be estimated with sufficient approximation by testing the water alkalimetrically, employing $\frac{1}{2}$ normal hydrochloric acid and methyl orange as indicator, at the ordinary temperature, until the first reddish tint appears. When employing 200 c.c. of the water for this test, the number of c.c. of $\frac{1}{2}$ normal acid used, multiplied by 3.5, indicates the English degrees of temporary hardness (for French degrees multiply by 5, for German degrees by 2.8).

Where feed-water, purified by means of sodium carbonate, is tested in this way, an error may be caused by the presence of an excess of Na_2CO_3 , which makes the hardness appear too high. In such cases the 200 c.c. of water employed should be boiled in a porcelain dish for some time, the precipitated carbonates removed by filtration, and the filtrate titrated as above. The acid then used corresponds to the Na_2CO_3 and a little unprecipitated MgCO_3 .

(b) *Total Hardness*.—Add to 200 c.c. of the feed-water hydrochloric acid in slight excess, boil down to about 50 c.c.; wash this into a 100 c.c. flask, neutralise exactly with caustic soda solution, employing methyl orange as indicator; add 20 c.c. of a mixture of equal volumes of $\frac{1}{2}$ normal caustic soda solution and $\frac{1}{2}$ normal sodium carbonate solution, boil, allow to cool, fill up the flask to the 100 c.c. mark with distilled water, pour through a dry filter, and estimate the unsaturated alkali in 50 c.c. of the filtrate by $\frac{1}{2}$ normal hydrochloric acid and methyl orange. Multiply the c.c. of acid used by 2, and deduct this from 20; the remainder = a shows the alkali consumed for precipitating the alkaline earths contained in 200 c.c. of water. The total hardness is hence = $3.5a$ in English degrees, $5a$ in French, $2.8a$ in German degrees. This process is accurate also in presence of magnesia. By deducting the degrees of alkalinity found in a from the total hardness found in b , the *permanent hardness* is obtained—i.e. that which is caused by calcium sulphate.

Water having a total hardness of less than 8° (English) is considered as *soft*, from 8° to 15° as *moderately hard*, above 15° as *hard*.

(c) *Residue on Evaporation*.—In the case of water containing but little MgO , a convenient check for the total hardness—i.e. the sum of alkalinity a and permanent hardness b —is afforded by evaporating 500 c.c. down to dryness, heating to decompose the organic matter, moistening with a solution of CO_2 in distilled water, and drying at 110° . Since the degrees of hardness are all calculated for CaO , the value of c will not be quite equal to $a + b$, if any considerable quantity of magnesia is present, and this indirectly proves the presence of more magnesia than usual.

2. *Estimation of the Reagents (lime water and sodium carbonate) required for Purifying Water*.—Add to 500 c.c. of the water 10 c.c. of a $\frac{1}{2}$ normal sodium carbonate solution, evaporate to dryness, take up the residue with a small quantity of water, filter through a small filter, wash till there is no further alkaline reaction, and estimate the unconsumed sodium carbonate in the filtrate plus washings by titrating with methyl orange and $\frac{1}{2}$ normal hydrochloric acid. If a c.c. of $\frac{1}{2}$ normal sodium carbonate are used in the titration, then $2a \times 0.0106$ shows the grams of pure sodium carbonate required per litre of the water for removing the calcium sulphate—i.e. the *permanent hardness*.

The amount of *lime water* required for removing the *temporary*

hardness is estimated as follows:—To 500 c.c. of water add 100 c.c. of clear lime water, after having previously determined its percentage of CaO by titrating with $\frac{1}{5}$ normal hydrochloric acid and phenolphthalein (methyl orange is not applicable in this case, because this would indicate also the CaCO_3 present in small quantities along with $\text{Ca}(\text{OH})_2$, which would be wrong). Heat the mixture during half an hour in a covered flask (to keep out CO_2), allow to cool, pour through a dry filter, and titrate, without delay, 500 c.c. of the filtrate. The HCl now used, increased by one-fifth (since the original 500 c.c. of water had been brought to 600 c.c.), shows the quantity of lime not used up. By deducting this from the CaO originally contained in 100 c.c. of the lime water, the quantity of CaO required for destroying the temporary hardness of $\frac{1}{2}$ litre of the water to be tested is ascertained.

IV. SULPHURIC ACID MANUFACTURE.

A.—Brimstone.

1. *Moisture*.—This should be estimated by drying an average sample of 100 g. at 70° for a few hours, in an oven or water-bath. The sample must be prepared without losing any moisture during the operation; the brimstone for this purpose must, therefore, not be ground, but only coarsely crushed, as quickly as possible.

2. *Bituminous Substances* (Fresenius).—Remove the sulphur by heating the sample for some time a little over 200° , taking care that it does not take fire, weigh the residue, and deduct the ash found in No. 3.

3. *Ash*.—Burn 10 g. in a porcelain dish and weigh the residue. Some samples of brimstone contain carbonaceous matter. In this case (which is easily recognised by the appearance of the sample) the flame must be removed immediately after the sulphur has been burned, and before the carbon has taken fire, so that the latter is not calculated as sulphur.

4. *Arsenic*.—Treat 10 g. brimstone with dilute ammonium hydroxide at 70° to 80° , in order to dissolve the As_2S_3 , filter, neutralise the filtrate exactly with dilute nitric acid, and titrate with decinormal silver nitrate solution, until a drop gives a brown colour with a solution of neutral potassium chromate. Each c.c. of the silver nitrate solution indicates 0.041 per cent. As_2S_3 . If the arsenic should be present as ferric or calcium arsenate (this never occurs in the case of native brimstone, but it may do so in the case of sulphur recovered from Leblanc soda residue), the sample must be extracted with carbon disulphide, the residue oxidised by aqua regia, and the sulphur estimated as in pyrites (see below).

5. *Direct Estimation of the Total Sulphur* (Pfeiffer).—Shake a weighed sample of powdered sulphur with exactly four times the

quantity of pure carbon disulphide, filter, reduce the temperature to 15°, and ascertain the specific gravity of the solution. The following table (abridged from the original) shows the number of parts of sulphur dissolved by 100 parts by weight of CS₂ at 15° for various specific gravities found :—

| Specific Gravity. | Sulphur Dissolved. | Specific Gravity. | Sulphur Dissolved. | Specific Gravity. | Sulphur Dissolved. |
|-------------------|--------------------|-------------------|--------------------|-------------------|--------------------|
| 1·2708 | 0·0 | 1·3087 | 8·5 | 1·3426 | 17·0 |
| 1·2731 | 0·5 | 1·3108 | 9·0 | 1·3445 | 17·5 |
| 1·2754 | 1·0 | 1·3129 | 9·5 | 1·3463 | 18·0 |
| 1·2779 | 1·5 | 1·3150 | 10·0 | 1·3481 | 18·5 |
| 1·2800 | 2·0 | 1·3170 | 10·5 | 1·3500 | 19·0 |
| 1·2833 | 2·5 | 1·3190 | 11·0 | 1·3517 | 19·5 |
| 1·2857 | 3·0 | 1·3211 | 11·5 | 1·3536 | 20·0 |
| 1·2870 | 3·5 | 1·3231 | 12·0 | 1·3553 | 20·5 |
| 1·2894 | 4·0 | 1·3251 | 12·5 | 1·3571 | 21·0 |
| 1·2916 | 4·5 | 1·3271 | 13·0 | 1·3587 | 21·5 |
| 1·2938 | 5·0 | 1·3291 | 13·5 | 1·3605 | 22·0 |
| 1·2960 | 5·5 | 1·3311 | 14·0 | 1·3622 | 22·5 |
| 1·2982 | 6·0 | 1·3330 | 14·5 | 1·3640 | 23·0 |
| 1·3003 | 6·5 | 1·3350 | 15·0 | 1·3657 | 23·5 |
| 1·3024 | 7·0 | 1·3369 | 15·5 | 1·3674 | 24·0 |
| 1·3045 | 7·5 | 1·3388 | 16·0 | 1·3692 | 24·5 |
| 1·3066 | 8·0 | 1·3408 | 16·5 | 1·3709 | 25·0 |

6. *Selenium* is found by fusing a sample with potassium nitrate, dissolving the mass in hydrochloric acid, and treating with sulphur dioxide, which precipitates the selenium.

7. *The degree of fineness* of ground brimstone is estimated in France by means of Chancel's sulphurimeter, *i.e.* a glass tube, closed at one end, provided with a glass stopper at the other, and graduated in 100 parts. In this, the ground brimstone is shaken up for some time with pure, anhydrous ether, and after allowing the tube to rest in a vertical position, the number of divisions occupied by the brimstone is read off (degrees Chancel).

B.—Spent Oxide of Gas-works.

The Spent Oxide Association advise the following procedure :—

Sampling.

Samples sent for quotation purposes are often assumed to represent bulk deliveries. This is almost impossible to be the case, as the bulk of the oxide may subsequently dry further or become damper owing to exposure. It is also possible that

portions of the heap of oxide which contain more or less sulphur may have become covered up and not included in the sample, however carefully taken. The spent oxide should, therefore, for invoicing purposes, be again sampled during loading and the greatest care taken to obtain correct proportions of lumps and fines, as these may contain different percentages of sulphur.

When deliveries are being made, daily samples are to be taken from every cart or wagon and collected in an air-tight receptacle. It cannot be too strongly emphasised that samples must not be allowed to lie about exposed to the risk of drying, but must be mixed, ground, and bottled each day. When the delivery of the parcel is completed, all the daily samples are to be at once mixed and broken down, and for this purpose coning and quartering is the best method. The well-mixed oxide is poured several times on to a given centre; this ensures an even distribution of both lumps and fines in the form of a cone. The cone is then flattened and quartered. Two opposite quarters are discarded and the remainder again mixed, coned, and quartered until the quantity is reduced to a convenient amount. This is now crushed until it will all pass through a $\frac{1}{4}$ -inch mesh sieve, and at once bottled.

The above operation must be carried out as quickly as possible to avoid alteration in the moisture content of the sample.

Samples should be of at least $\frac{1}{2}$ lb., and must be packed in air-tight bottles or tins; no other receptacle may be used. In taking the necessary samples, one must always be sealed and retained for reference.

Before carrying out the analysis, the whole of the sample is further intimately mixed and broken down and reduced to about 100 g., which is ground so that the whole quantity passes through a 20-mesh sieve.

Analysis.

Moisture.—Five g. are dried for three hours at 100° in a water oven. The loss of weight found on cooling and reweighing represents the moisture.

Sulphur and Tar.—The dried residue from the moisture determination is to be extracted for two hours in a Soxhlet's apparatus with freshly distilled carbon bisulphide. The carbon bisulphide is then distilled off, the flask cautiously blown out with air and dried for two hours at 100° in the water oven. The flask is then placed on a hot sand-bath until the sulphur has just fused, care being taken that no loss by overheating and volatilisation takes place. After the flask has cooled completely it is again carefully blown out with dry air and again weighed.

Estimation of the Sulphur.—Fifteen c.c. of concentrated (95 per cent.) sulphuric acid are poured on to the sulphur and tar in the flask, and the whole is heated for two hours at 100°

in a water oven. After cooling, the contents of the flask are diluted with water, filtered, washed free from acid, and dried. The dried filter paper with contents is placed in a Soxhlet's tube and again extracted with carbon bisulphide. The bisulphide is distilled off, and the residue fused exactly as described above.

The following alternative method gives reliable results and expedites the extraction by CS_2 :—

Place the 5 g. of dried spent oxide in a beaker with 25 c.c. of strong sulphuric acid and heat for four hours at 100° . Carefully dilute with distilled water, filter and wash free from acid, dry and extract with CS_2 in the usual way. Only one extraction with the solvent is necessary.

See also Spent Oxide, p. 243.

C.—Pyrites.

The average sample is taken and reduced according to the rules given on p. 103. Two samples are customary. (1) Coarsely ground for moisture; (2) finely ground for quality. For this purpose, the ore is reduced to an impalpable powder, by grinding it first in a steel, and then in an agate mortar, and is kept in well-sealed bottles.

1. *Moisture*.—The coarsely ground pyrites is dried at 105°C . until the weight remains constant.

2. *Quality*.—For the following tests, the finely ground average sample in a well-sealed bottle (not the dried sample) is employed. The analytical results are calculated for dry pyrites, for which reason a special estimation of moisture is made in the finely ground average sample.

Sulphur (Lunge's method).—About 0.5 g. of pyrites is treated with 10 c.c. of a mixture of 3 vols. nitric acid (spec. grav. 1.4) and 1 vol. strong hydrochloric acid, both ascertained to be absolutely free from sulphuric acid, in a 300 c.c. beaker, which is covered with a watch-glass to avoid any loss by spurting. At first, the acid is allowed to act in the cold, but the reaction is completed by heating upon a water-bath. The separation of a little free sulphur is observed sometimes when the temperature exceeds 60°C ., and must be oxidised by adding a little potassium chlorate. Evaporate to dryness on a water-bath, add 5 c.c. hydrochloric acid, evaporate once more (no nitrous fumes should escape now), add 1 c.c. concentrated hydrochloric acid and 100 c.c. of hot water, filter through a small filter, and wash with hot water. The insoluble residue may be dried, ignited and weighed. It may contain, in addition to silica and silicates, the sulphates of barium, lead, and even calcium, the sulphur of which, being non-available, is purposely neglected. (*N.B.*—If this residue is not to be estimated, the filtration need not be carried out, and

the elimination of the iron by precipitation with ammonia may be proceeded with as soon as all the nitric acid has been driven off, but for very accurate work, the removal is recommended.)

The filtrate and washings are saturated with ammonia, avoiding much excess (5 to 7 c.c. strong ammonia after neutralisation is sufficient), and kept at 60 to 70° C. for about 15 minutes before filtration. (The solution should still smell of ammonia, for if this is removed by boiling, some basic sulphate is precipitated.) The ferric hydroxide precipitate is filtered off and washed. This can be done in from half an hour to one hour, by employing the following precautions:—(1) Filter hot and wash on the filter with hot water, avoiding channels in the mass by churning up the whole precipitate thoroughly each time with the water; (2) employ sufficiently dense, but rapid, filtering paper; (3) use funnels, made exactly at an angle of 60°, whose tube is not too wide and is filled *completely* by the liquid running through. A filter pump also gives satisfactory results with the usual precautions.

The precipitate is washed until about 1 c.c. of the washings shows no turbidity on adding barium chloride solution, even after standing a few minutes. (If there is any doubt, the ferric hydroxide should be dissolved in hydrochloric acid and reprecipitated with excess of ammonia again. The two filtrates are then mixed. The complete absence of basic sulphates can be confirmed by drying the precipitated ferric hydroxide, fusing it with pure sodium carbonate and testing the aqueous solution of the melt for sulphates.)

If the filtrate and washings exceed 300 c.c., they should be concentrated by evaporation. The solution is neutralised by adding pure hydrochloric acid until methyl orange is just reddened, and then 1 c.c. of strong hydrochloric acid is added in excess. Then heat to boiling; remove the burner and add 20 c.c. of a boiling hot 10 per cent. solution of barium chloride, while stirring vigorously. The barium chloride solution is measured off roughly in a test tube provided with a mark, and boiled in the same tube; it is then poured into the hot liquid *all at once*, not drop by drop. An error is introduced by this procedure owing to the absorption of some barium chloride by the barium sulphate precipitate; but this just compensates with the loss caused by the slight solubility of barium sulphate in the hot solution containing free hydrochloric acid and ammonium chloride. A large excess of barium chloride must be avoided, or the results will turn out too high.

The precipitate is allowed to settle for about half an hour, and is then washed three or four times by decantation, with 100 c.c. of boiling water, until the liquid ceases to give an acid reaction. The precipitate is transferred to a filter, washed free from chloride, dried, ignited and weighed. It should be a

perfectly white and loose powder. One part of it is equal to 0.1373 sulphur.

3. *Copper*—(Method of the Duisburg Copper Co.).—Of the powdered pyrites, dried at 100° C., 5 g. is gradually dissolved in 60 c.c. of nitric acid, spec. grav. 1.2, in a flask placed in a slanting position. When the first violent reaction is over, the flask is heated and the evaporation continued until thick, white fumes of sulphuric acid escape. Dissolve the dry residue in 50 c.c. hydrochloric acid, spec. grav. 1.19, add 2 g. sodium hypophosphite, dissolved in 5 c.c. water, for the purpose of removing the arsenic and reducing the ferric chloride, boil for some time, then add an excess of concentrated hydrochloric acid, diluted with about 300 c.c. hot water, pass hydrogen sulphide into the liquid, separate the precipitate from the liquid by filtration, and wash it well. Pierce the filter paper with a glass rod, wash the precipitate back into the precipitating flask, dissolve the sulphides adhering to the filter and the principal portion of the precipitate by means of nitric acid, and evaporate the contents of the flask to dryness on the water-bath. Treat the residue with nitric acid and water, neutralise with ammonia, and add sulphuric acid in slight excess. After the liquid has cooled down, separate the clear liquid from the insoluble lead sulphate, etc., wash out the flask and filter with water containing a little sulphuric acid, add to the filtrate 3 to 8 c.c. nitric acid, spec. grav. 1.4, and precipitate the copper electrolytically. From the ascertained percentage of copper deduct 0.01 per cent. for bismuth and antimony.

4. *Lead* remains in the residue from the treatment with aqua regia (No. 2) or nitric acid (No. 3), as lead sulphate. This is extracted from the residue (preferably that from the nitric acid treatment) by heating with a concentrated solution of ammonium acetate. The solution is evaporated, with addition of a little pure sulphuric acid, the evaporation completed in a porcelain crucible, and the residue dried and ignited. One part $\text{PbSO}_4 = 0.6829 \text{ Pb}$.

5. *Zinc* is sometimes estimated in pyrites, because the sulphur combined with it is hardly recoverable in the pyrites burners. The following method of Messrs Hassreidter and Prost should be employed in this case, in lieu of Schaffner's method described subsequently for zinc blende, because in the case of pyrites the presence of iron renders gravimetric preferable to volumetric analysis:—Dissolve 1 g. pyrites in aqua regia, as described on p. 133, expel the nitric acid, take up the residue with about 20 c.c. concentrated hydrochloric acid, dilute with water, treat the acid solution with H_2S in order to precipitate lead, etc., filter, expel the H_2S from the filtrate by boiling, and oxidise the liquid with aqua regia. When cooled down, add ammonium carbonate until the precipitate formed redissolves but slowly, then add ammonium acetate, boil for a short time, and filter the liquid from the

precipitated basic ferric sulphate. As this contains a little zinc, dissolve it in hydrochloric acid, precipitate it again as above, and repeat this treatment until no more zinc is found in the filtrate. The united filtrates are concentrated by evaporation. Then precipitate the zinc in the hot solution by H_2S , allow to stand for twenty-four hours, pour off the clear liquid, filter, wash the ZnS , dissolve it (without removing the filter) in dilute HCl , boil off the H_2S , precipitate with sodium carbonate, wash the ZnCO_3 , dry and ignite it. One part $\text{ZnO} = 0.8034 \text{ Zn}$. For very accurate work the SiO_2 , Fe_2O_3 , and Al_2O_3 retained in the ZnO should be estimated and deducted, but this is very rarely necessary.

6. *The Carbonates* (of Ca , etc.) are sometimes estimated in pyrites, because they convert a certain quantity of sulphur into sulphate. Since their quantity is always small, the CO_2 is estimated directly by expelling with strong acids, and is easily estimated gravimetrically by absorbing it in soda-lime, etc., or, more quickly, by decomposing a weighed quantity with hydrochloric acid in an evacuated vessel and measuring the CO_2 evolved in a Hempel pipette.

7. *Arsenic*.—Reich's method, modified by M'Cay :—Decompose 0.5 g. pyrites by concentrated nitric acid in a porcelain crucible, remove the free acid by evaporation, but not to complete dryness, add 4 g. sodium carbonate, heat on the sand-bath until the mass is quite dry, add 4 g. potassium nitrate, and heat until the mass has fused quietly for ten minutes. After cooling, wash it with hot water, acidulate the filtered solution with a little nitric acid, heat for some time till all CO_2 is expelled, add silver nitrate, and neutralise carefully with dilute ammonia. The precipitate formed contains all the arsenic as Ag_3AsO_4 . Dissolve it in dilute nitric acid, and either estimate the silver volumetrically by ammonium thiocyanate (Volhard's method), or evaporate the solution in a porcelain dish, dry, and weigh the residue. One part $\text{Ag}_3\text{AsO}_4 = 0.1620 \text{ As}$, or 1 part $\text{Ag} = 0.2316 \text{ As}$.

8. *Selenium*.—Twenty to 30 g. of pyrites are dissolved in hydrochloric acid (spec. grav. 1.19) and potassium chlorate. After filtering from gangue, the iron is reduced to the ferrous state by means of zinc, more hydrochloric acid is added, the solution boiled and the selenium precipitated by stannous chloride. Since it may contain arsenic, it is collected on an asbestos filter, dissolved in potassium iodide, and reprecipitated by hydrochloric acid and sulphur dioxide.

D.—Burnt Pyrites (Cinders).

1. *Sulphur*.—Mix exactly 2 g. sodium bicarbonate of known alkalimetric value in a nickel crucible of 20 or 30 c.c. capacity, intimately with 3.207 g. of ground cinders, by means of a glass rod

flattened at the end. Heat the crucible by a small gas-flame, the point of which reaches just to the bottom of the crucible, for ten minutes. Stir the mass up again, heat it again for fifteen minutes by a stronger flame, but not to the fusing point. During the heating the crucible should be covered, and no stirring should take place during this time to prevent the escaping CO_2 from carrying away any dust. Empty the contents of the crucible into a porcelain dish, wash it out with water, add a concentrated solution of sodium chloride, free from magnesium chloride and perfectly neutral (without this addition it is difficult to avoid some ferric oxide passing through the filter later on), boil for ten minutes, filter, wash the insoluble residue till there is no alkaline reaction, allow the filtrate, etc., to cool down, and titrate it with methyl orange and normal hydrochloric acid (1 c.c. = 0.05300 Na_2CO_3 , indicating 0.01604 S). If we call the number of c.c. of the acid required by 2 g. bicarbonate = a , and the c.c. of acid used for titrating = b , the percentage of sulphur in the cinders corresponds to $\frac{a-b}{2}$.

2. *Copper* is estimated as in fresh pyrites, but the solution of 1 g. of the sample is effected by hydrochloric acid with only a few drops of nitric acid, and *no* deduction for Bi and Sb is made from the electrolytically estimated Cu.

3. *Iron*.—Dissolve 0.5 g. cinders in concentrated hydrochloric acid by prolonged heating; reduce the boiling solution by zinc, free from iron, or more conveniently by stannous chloride, the excess of the latter being removed by a little mercuric chloride solution; pour the solution thus obtained into a half-litre of water, to which about 2 g. manganous sulphate has been added, and which has been just reddened by one or two drops of potassium permanganate. Determine the iron by titrating with decinormal potassium permanganate, each c.c. of which indicates 0.005584 g., or in 0.5 g. cinders 1.117 per cent. Fe.

E.—Zinc Blende.

1. *Total Sulphur*.—Decompose 0.5 of the finely ground sample by pure fuming nitric acid, cooling the beaker until the first violent reaction is over, and add hydrochloric acid, drop by drop, gently heating, until the decomposition is finished. Remove the iron by precipitation with ammonia, as in the case of pyrites (p. 134), and precipitate the sulphate by adding the requisite quantity of the dilute hot solution of barium chloride, all at once, in which case the BaSO_4 remaining in solution is just compensated by the BaCl_2 carried down with the precipitate (compare p. 134).

2. *Zinc*.—The following modification of Schaffner's method is employed at the Rhenish and Belgian zinc works, as com-

municated to the author by Messrs Hassreidter and Prost :—Treat 2.5 g. of the finely ground blende (dried at 100° C.) in a 250 c.c. Erlenmeyer flask with 12 c.c. fuming nitric acid, first without heating, then heating gently until no more red vapours come off. Add 20 to 25 c.c. concentrated hydrochloric acid, evaporate to dryness on a sand-bath, dissolve in 5 c.c. hydrochloric acid and a little water, heat for some time, add 50 or 60 c.c. water, and heat to 60 or 70° C. until everything except gangue and sulphur has passed into solution. Pass a moderate current of H_2S into the solution, and gradually add, with continuous stirring, 50 to 100 c.c. water, until all Pb and Cd have been precipitated. This will be recognised by the fact that the bubbles of gas evolved are transparent. Any excessive dilution or too much prolonged treatment with H_2S must be avoided. Filter and wash with 100 c.c. sulphuretted hydrogen water, to which 5 c.c. hydrochloric acid has been added, until a drop of the filtrate gives no reaction for zinc with ammonium sulphide. Boil the filtrate and washings (together about 300 c.c.) in order to expel the H_2S (test by lead paper), and oxidise the ferrous salt by adding 5 c.c. concentrated nitric acid and 10 c.c. hydrochloric acid. When partially cooled down, put the solution into a half-litre flask, add 100 c.c. ammonia (spec. grav. 0.9 to 0.91) and 10 c.c. of a cold saturated solution of ammonium carbonate, shake well and allow to cool. This solution we call A.

In the meantime an ammoniacal zinc solution of known strength, the "titre," is prepared by dissolving a quantity of chemically pure zinc, approximately equal to that contained in the ore, in another half-litre flask, in 5 c.c. nitric acid + 20 c.c. hydrochloric acid, adding 250 c.c. water, 100 c.c. ammonia, and 10 c.c. of ammonium carbonate solution, shaking up and allowing to stand till cool. (If manganese be present, add 10 c.c. hydrogen peroxide before adding the ammonia.) This solution we call B. When all is cool, fill both flasks up to the mark, and filter the solution A (made from the ore) through a dry pleated filter. For the titration itself take from each of the solutions A and B 100 c.c., run this into stout glass cylinders ("battery glasses") and dilute each with 200 c.c. water. The titration is effected by a concentrated solution of commercial crystallised sodium sulphide, diluted with ten or twenty times its volume of water and indicating per c.c. 0.005 to 0.010 g. Zn. This solution is placed in two 50 c.c. burettes, standing side by side, and is run by turns into the zinc solutions A and B. At first 2 or 3 c.c. less than is ultimately required is run in. Agitate the solutions and place at the same time a drop of each, by means of a thin glass rod, on to a strip of sensitive lead paper. After the action has lasted fifteen or twenty seconds, blow away the drops by means of a small wash-bottle and continue the addition of Na_2S , until both drops, after acting for the same time, produce a slight but distinct

brownish colour of the same intensity. If too much liquid has been used in these drop tests, the titration must be repeated once or twice; at all events, the final reaction must take place equally in both glasses, and the readings must be accurate to 0.05 c.c.

If we call the quantity of pure zinc weighed out as "titre" a , that of the c.c. sodium sulphide solution used for the "titre" b , and the c.c. used for 100 c.c. of the ore solution ($=0.5$ g. ore) c , the expression $\frac{40ac}{b}$ gives the percentage of zinc in the ore.

For exact estimations, a quantity of ferric chloride, equal to the content of iron in the ore, is added to the "titre," in order to meet the objection that the ferric hydroxide may carry down a little zinc.

Some blends, containing a large proportion of silicates, obstinately resist the ordinary methods of testing (Jensch, *Zsch. f. angew. Chem.*, 1894, p. 155).

3. *Lead*.—The sulphides precipitated in No. 2 are, if necessary, digested with a concentrated solution of sodium sulphide; then dilute, filter, wash the residue, dissolve it (together with the filter) in nitric acid (spec. grav. 1.20), filter, add an excess of sulphuric acid, evaporate to dryness, and weigh the lead as sulphate. One part $\text{PbSO}_4 = 0.6831$ Pb.

4. *Lime and Magnesia* are estimated, because they form sulphates in the roasting process. Digest 2.5 g. blende with 50 c.c. dilute sulphuric acid (1 : 10), with application of heat, decant the clear portion; repeat this treatment once or twice, wash the residue, expel the H_2S from the filtrates by boiling, oxidise with bromine water, precipitate with ammonium carbonate, and in the filtrate precipitate first the calcium by ammonium oxalate (weigh this as CaO after strongly igniting), and in the filtrate from this the magnesium by ammonium phosphate (compare p. 175).

5. *Arsenic* is estimated as described on p. 136.

6. *Carbon Dioxide* may be estimated as in pyrites, pp. 136 and 137. This is useful, even when CaO and MgO are estimated, since blende contains sometimes ferrous and zinc carbonate.

7. *Available Sulphur*.—From the total sulphur found in No. 1 deduct:

| | | | |
|--|--------------|--------------|---------------|
| For each part of Pb found in No. 3, 0.1550 part. | | | |
| | CaO | " | 4, 0.5715 " |
| " | " | MgO | " 4, 0.7944 " |

The remainder indicates the sulphur available for the manufacture of sulphuric acid. The S of BaSO_4 , etc., remains in the residue from the dissolving process.

F.—Cinders from Blende.

1. *Sulphur* (according to Lunge and Stierlin, *Zsch. f. angew. Chem.*, 1906, p. 26).—The process is carried out as described for pyrites cinders on p. 136, but 2 g. ground potassium chlorate is added to the mixture. The bottom of the crucible should finally be at a red heat, but the contents should merely frit together, not fuse entirely. The crucible must be covered during the heating, and its contents must not be stirred up. The calculation is as on p. 137—that is, the percentage of S = $\frac{a-b}{2}$.

An addition of potassium chlorate is already required in the case of cinders from iron pyrites containing much zinc. In case the cinders contains upwards of 6 per cent. S, the mixture should be: 1.603 g. cinders, 2.000 g. NaHCO_3 , 4.0 g. KClO_3 , 2–3 g. ferric oxide (free from S). The percentage of sulphur is then = $a-b$, where a is the c.c. of normal acid corresponding to the 2.000 g. bicarbonate, b the c.c. of acid required for titration after the heating.

This process is also applicable to fresh (unroasted) blende, by using the following mixture: 0.3207 g. blende, 2.000 g. NaHCO_3 , 2 g. KClO_3 , 2 g. Fe_2O_3 ; percentage of S = 5 ($a-b$).

A crude test is made by the foreman at the works, in this manner: he heats a sample of the cinders with 10 c.c. hydrochloric acid (1:2 water) in a flask, holding in its neck a strip of paper soaked in a neutral or faintly alkaline solution of lead acetate, and he judges of the more or less complete state of roasting by the depth of the brown colour developed on the paper.

2. *Zinc*, as on p. 135.

G.—Gases.**I. Chamber Process.**

1. *Burner Gases*.—(a) SO_2 is estimated by Reich's method. The gas is aspirated through a solution of iodine, contained in a wide-necked 200 c.c. bottle, and coloured blue by starch solution, till the colour is just discharged. This bottle is connected with a larger bottle, converted into an aspirator by having a tap near the bottom, or by a siphon with a pinchcock. Water is run from this into a graduated 250 c.c. jar. The iodine bottle is shaken up during the aspiration, and at the moment when the colour is discharged, the tap of the aspirator is closed and the volume of water in the jar is read off. It is equal to the volume of the water run out, increased by that of the SO_2 absorbed. The absorbing-bottle is charged with 10 c.c. of a decinormal solution of iodine (12.692 g. iodine per litre, preparation and valuation as on p. 114), along with about 50 c.c. of water, a little starch solution, and a little sodium bicarbonate. The above quantity of iodine is = 0.03203 g. SO_2 = 10.93 c.c. at 0° C. and a pressure of

760 mm. The latter figure, multiplied by 100 and divided by $10\cdot93$ c.c. + the volume of the water run out, yields the percentage of SO_2 in the gas by volume.

This calculation is saved by the following table, in which the $10\cdot93$ c.c. are taken into account.

| Cubic Centimetres. Water Collected. | Volume per cent. SO_2 in Kiln Gas. | Cubic Centimetres. Water Collected. | Volume per cent. SO_2 in Kiln Gas. |
|--|--|--|--|
| 80·1 | 12·0 | 125·7 | 8·0 |
| 84·1 | 11·5 | 134·8 | 7·5 |
| 88·4 | 11·0 | 145·2 | 7·0 |
| 93·2 | 10·5 | 157·2 | 6·5 |
| 93·4 | 10·0 | 171·2 | 6·0 |
| 104·1 | 9·5 | 187·8 | 5·5 |
| 110·5 | 9·0 | 207·8 | 5·0 |
| 117·7 | 8·5 | | |

In this no notice is taken of temperature and barometer. If these are to be observed, the volume read off is reduced to 0° and 760 mm. by the Tables 12 and 13, and then looked up in the above table.

(b) Since Reich's test takes no account of the SO_3 always present in burner gases, it is preferable to estimate the *total acids* ($\text{SO}_2 + \text{SO}_3$), either along with the test (a) or exclusively. This is performed in the same apparatus, but the absorbing-bottle is preferably provided with a gas entrance tube, closed at the bottom and perforated by numerous pinholes, through which the gas issues in small bubbles. The gas is passed through a solution of decinormal sodium hydroxide, coloured by phenolphthalein, until the colour is just discharged. The calculation is made as for pure SO_2 , employing the table given in (a) (Lunge, *Zsch. f. angew. Chem.*, 1890, p. 563).

In both cases—(a) and (b)—an error is sometimes caused by arsenious oxide collecting in the aspirating tube; this is avoided by filtering the gases through asbestos.

2. *Chamber Gases.*—In these, *sulphur dioxide* and *nitrous gases* are estimated (as described by Raschig, *Zsch. angew. Chem.*, 1909, xxii., p. 1182) by means of a Reich apparatus (p. 140), charged with 10 c.c. decinormal iodine solution, 100 c.c. water, a little starch solution, and 10 c.c. of a cold saturated solution of sodium acetate. The estimation is performed as described on p. 140, taking care that no droplets of sulphuric acid get into the iodine solution, which is effected by passing the chamber gases through glass wool. The calculation of SO_2 is effected as described *supra*. In order to estimate the nitrous gases, add, after estimating the SO_2 , a drop of phenolphthalein solution

to the decolorised solution, and titrate with decinormal caustic soda solution up to the appearance of a red colour. From the number of c.c. used deduct 10 c.c. for the hydriodic acid and 10 c.c. for the sulphuric acid formed, according to the equation : $\text{SO}_2 + \text{I}_2 + 2\text{H}_2\text{O} = \text{H}_2\text{SO}_4 + 2\text{HI}$. The c.c. of decinormal soda solution, used over and above these 20 c.c., indicate nitric or nitrous acid.

3. *Chamber Exit Gases.*—(a) *Oxygen.* Before estimating this, the acids are removed from the gas by washing with a solution of potassium or sodium hydroxide. Single samples can be taken at odd times during the day, but it is recommended to take an average sample for the whole day, by aspirating at least 10 or 20 litres of gas, and analysing a portion of this. The estimation of oxygen is best made by moist phosphorus in an Orsat apparatus with two absorbing tubes, one of which is filled with potassium hydroxide solution for removing the acids, the other with small pieces of phosphorus. The manipulation is exactly as in testing flue gases, but it should be observed that the temperature must be at least 16° , better 18°C. , otherwise the tube must be warmed a little.

(b) *Sulphur and Nitrogen Acids.*—The different acid compounds of sulphur and nitrogen are estimated together, whatever their degree of oxidation. A continuous test over twenty-four hours is taken of the gases escaping from the exit pipes of the Gay-Lussac towers, aspirating at least one cubic foot per hour by means of any aspirator acting at a constant rate and recording the volume of gas = V by means of gauging the aspirator or by a gas meter. The volume V is reduced to 0°C. and 760 mm. pressure (= 32°F. and 29.92 inches*) by the Tables 12 and 13, and is called V^1 . In order to allow comparisons, the number of cubic feet of chamber space per pound of sulphur burnt and passing into the chambers is recorded, excluding towers, but including tunnels, the amount of sulphur being taken by the weekly average, each firm to state the distance of the testing hole from the point at which the gases leave the Gay-Lussac towers. The absorption apparatus consists of four bottles or tubes, containing not less than 100 c.c. of absorbing liquid each, with a depth of at least 3 inches in each bottle, the aperture of inlet tubes not to exceed $\frac{5}{16}$ inch in diameter, and to be measured by a standard wire. The first three bottles each contain 100 c.c. of normal caustic soda solution (40.01 g. per litre), the fourth 100 c.c. distilled water. The caustic soda used must be free from nitrogen acids. The gases are tested (1) for total acidity, stated in grains of SO_3 per cubic foot of gas, or in grams per cubic metre; (2) sulphur acids; (3) nitrogen acids, both stated in grains of S and N per cubic foot (or grams per cubic metre). The

* The law prescribes the cubic feet to be measured at 60°F. and 80 inches, which necessitates the use of other tables or factors than those mentioned in the text; but the difference is hardly perceptible, and certainly within the limits of experimental error.

analysis is carried out as follows:—The contents of the four bottles are united, taking care not to unnecessarily augment the bulk of the liquids, and are divided into three equal parts, one of which is reserved for accidents, etc. The first part is titrated with normal sulphuric acid (49.04 g. H_2SO_4 per litre), to ascertain total acidity. The number of cubic centimetres of acid necessary for neutralisation is called x . The second part of the liquid is gradually poured into a warm solution of potassium permanganate, strongly acidified with pure sulphuric acid. A small excess of permanganate must be present, and must be afterwards reduced by the addition of a few drops of sulphurous acid solution, until only a faint red tint is visible. Now all nitrogen acids are present as HNO_3 , but no excess of SO_2 . The HNO_3 is estimated by its action on FeSO_4 . Twenty-five c.c. of a solution, containing per litre 100 g. crystallised ferrous sulphate and 100 c.c. pure sulphuric acid (the same solution which is used for estimating MnO_2 , p. 182), are put into a flask, 20 c.c. to 25 c.c. pure concentrated sulphuric acid is added, the mixture is allowed to cool, and the other mixture, treated with permanganate, etc., is added. The flask is closed by a cork with glass tubes. A current of CO_2 passes through and issues beneath the surface of some water, to prevent entrance of air. First, all the air is expelled in this way by means of an apparatus giving a constant current of CO_2 ; then the solutions are introduced, and the contents of the flask are heated to boiling, till the dark colour produced by the formation of NO has changed to a clear light yellow. This takes from a quarter of an hour to one hour, according to the quantity of HNO_3 present and that of the sulphuric acid added. The unoxidised ferrous sulphate is titrated by a seminormal permanganate solution (yielding 0.004 g. oxygen per cubic centimetre—compare p. 114). The cubic centimetres used = y . Since the titre of the iron solution changes somewhat quickly, it should be tested daily by taking out 25 c.c. with the same pipette as is used for the above operation, and ascertaining the amount of permanganate required for oxidising it = z c.c. The data required are found by the following equations:—

1. *Total Acidity* in grains per cubic metre =

$$\text{SO}_3 = \frac{0.120(100 - x)}{\sqrt{V}}$$

2. *Sulphur* in grains per cubic metre =

$$S = \frac{0.008(600 - 6x - z + y)}{\sqrt{V}}$$

3. *Nitrogen* in grains per cubic metre =

$$N = \frac{0.007(z - y)}{\sqrt{V}}$$

1. *Total Acidity* in grains per cubic foot =

$$\text{SO}_3 = \frac{1.852(100 - x)}{\sqrt{V}}$$

2. *Sulphur* in grains per cubic foot =

$$S = \frac{0.12346(600 - 6x - z + y)}{\sqrt{V}}$$

3. *Nitrogen* in grains per cubic foot =

$$N = \frac{0.10803(z - y)}{\sqrt{V}}$$

The legal limit for total acidity in the lead-chamber process is 4 grains of SO_3 per cubic foot, before admixture with air, smoke, or other gases; for the contact process, the "best practicable means" are to be adopted.*

In lieu of the above process, it is customary in works practice, and for the purposes of the Alkali Act, to estimate the total acidity in the chamber exit gases, by means of the bellows aspirator, as described under chimney-testing, on p. 176.

The Technical Index to the Alkali Reports (1919), pp. 46-47, should be consulted for detailed information on this subject.

The test is carried out as follows:—

About 300 c.c. of distilled water with 5 to 10 c.c. of neutral hydrogen peroxide ("10 volume H_2O_2 ") is introduced into the bellows. The gases are drawn from the exit pipe through a glass tube, and are washed thoroughly after each aspiration by shaking the contents of the aspirator vigorously. When a sufficient

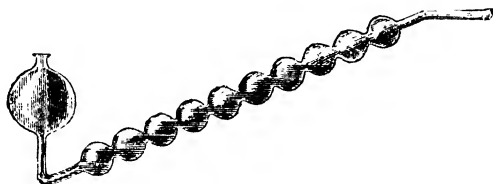


FIG. 10.

volume of gas has been withdrawn ($\frac{1}{2}$ cubic foot is usually enough), any acid which may have condensed in the glass tube is washed back into the bellows and the liquid then transferred to a porcelain dish and titrated with $\frac{N}{2}$ sodium carbonate solution, using methyl orange as indicator.

A.B.—Hydrogen peroxide should be kept in a cool place and protected from the action of light; for this purpose bottles of a brown or deep green colour should be used, not blue or colourless ones. (See Dr T. L. Bailey's report on experiments on the action of light on hydrogen peroxide in the 46th Annual Report, 1909, p. 110.)

(c) *Nitric Oxide* (NO) may be present in the exit gases after passing through the absorbing-bottles. If it is to be estimated, an absorption-tube (Fig. 10)† is interposed between the tubes of the apparatus described above and the aspirator. This tube contains 30 c.c. of seminormal permanganate and 1 c.c. of sulphuric acid, spec. grav. 1.25. The gas is passed through for twenty-

* Alkali Act, 1906.

† This shape of bulb-tubes has been found to be far superior to any other form of absorption-tubes tried.

four hours, and the tube then emptied and washed out. Now add 50 c.c. ferrous sulphate solution, corresponding to 2 z permanganate (compare last paragraph), and retitrate the decolorised liquid with permanganate. The quantity of the latter now used is called u . The NO has consumed $(30 + u - 2z)$ c.c. permanganate, which is equal—

In grams of nitrogen per cubic
metre of the volume V^1 .

$$N = \frac{0.007 (30 + u - 2z)}{3V^1}$$

In grains of nitrogen per cubic
foot.

$$N = \frac{0.10803 (30 + u - 2z)}{3V^1}$$

II. Contact Process.

1. The *Entering Gases* are analysed like those of the Chamber Process (pp. 140 and 141).

2. The *Catalysed Gases* are passed through a measured quantity of iodine solution and then through a vessel containing thio-sulphate solution. The non-consumed iodine is retitrated by thiosulphate, and the total acidity is ascertained by baryta solution or by decinormal soda solution, with phenolphthalein as indicator, making the same deduction as prescribed in the Reich-Raschig method (p. 141). If the c.c. of $1/10 N$ iodine solution consumed are designated by a , and those of $1/10 N$ soda solution (or baryta solution) by b , the formula $x = 0.003203a$ indicates the quantity of non-catalysed SO_3 , and $y = 0.004 (b - 2a)$ that of the SO_3 formed. The yield of SO_3 in volume per cent. is shown by the formula—

$$\frac{(b - 2a)100}{b - a}.$$

H.—Sulphuric Acid.

1. *Specific Gravity*.—The specific gravity tables of sulphuric acid refer, of course, to *chemically pure acid*. Since, in the case of high-grade acids, the impurities always present in commercial acids quite sensibly increase the specific gravity, the table in the case of acids over 90 per cent. H_2SO_4 should only be employed for the private use of the works, but *sales should always be effected on the basis of a real analysis*, as described later on under No. 12, p. 162.

The following tables have been recalculated by the editor from the data of Domke and Bein, who investigated the density and expansion of sulphuric acid on behalf of the *Normaleichungskommission* at Berlin. There are many variations in these recalculated figures from those given in the last edition of this book.

1. SPECIFIC GRAVITY OF SULPHURIC ACID.

| Degrees Twaddell. | Specific gravity at 15°/4°. | 100 parts by weight contain | | Kilos H ₂ SO ₄ per litre. | 1 Cubic foot of acid | |
|----------------------|-----------------------------------|--------------------------------|----------------------------------|---|-----------------------|--|
| | | SO ₃ . | H ₂ SO ₄ . | | weighs lb. avoird. | contains lb. H ₂ SO ₄ . |
| 1 | 1.005 | 0.69 | 0.84 | 0.0084 | 62.74 | 0.53 |
| 2 | 1.010 | 1.28 | 1.57 | 0.0159 | 63.05 | 0.99 |
| 3 | 1.015 | 1.89 | 2.31 | 0.0234 | 63.37 | 1.46 |
| 4 | 1.020 | 2.48 | 3.04 | 0.0310 | 63.68 | 1.94 |
| 5 | 1.025 | 3.10 | 3.79 | 0.0388 | 63.99 | 2.42 |
| 6 | 1.030 | 3.70 | 4.53 | 0.0467 | 64.30 | 2.91 |
| 7 | 1.035 | 4.31 | 5.27 | 0.0546 | 64.61 | 3.40 |
| 8 | 1.040 | 4.90 | 6.00 | 0.0624 | 64.93 | 3.90 |
| 9 | 1.045 | 5.49 | 6.72 | 0.0702 | 65.24 | 4.38 |
| 10 | 1.050 | 6.08 | 7.44 | 0.0781 | 65.55 | 4.88 |
| 11 | 1.055 | 6.66 | 8.15 | 0.0860 | 65.86 | 5.37 |
| 12 | 1.060 | 7.24 | 8.86 | 0.0939 | 66.18 | 5.86 |
| 13 | 1.065 | 7.81 | 9.56 | 0.1018 | 66.49 | 6.36 |
| 14 | 1.070 | 8.39 | 10.26 | 0.1098 | 66.80 | 6.86 |
| 15 | 1.075 | 8.96 | 10.96 | 0.1178 | 67.11 | 7.36 |
| 16 | 1.080 | 9.53 | 11.66 | 0.1259 | 67.42 | 7.86 |
| 17 | 1.085 | 10.09 | 12.35 | 0.1340 | 67.74 | 8.37 |
| 18 | 1.090 | 10.65 | 13.03 | 0.1420 | 68.05 | 8.87 |
| 19 | 1.095 | 11.21 | 13.71 | 0.1501 | 68.36 | 9.37 |
| 20 | 1.100 | 11.76 | 14.39 | 0.1583 | 68.67 | 9.88 |
| 21 | 1.105 | 12.32 | 15.07 | 0.1665 | 68.98 | 10.40 |
| 22 | 1.110 | 12.86 | 15.73 | 0.1746 | 69.30 | 10.90 |
| 23 | 1.115 | 13.40 | 16.40 | 0.1829 | 69.61 | 11.42 |
| 24 | 1.120 | 13.95 | 17.07 | 0.1912 | 69.92 | 11.93 |
| 25 | 1.125 | 14.49 | 17.73 | 0.1995 | 70.23 | 12.45 |
| 26 | 1.130 | 15.03 | 18.39 | 0.2078 | 70.55 | 12.97 |
| 27 | 1.135 | 15.56 | 19.04 | 0.2161 | 70.86 | 13.49 |
| 28 | 1.140 | 16.09 | 19.69 | 0.2245 | 71.17 | 14.01 |
| 29 | 1.145 | 16.62 | 20.34 | 0.2329 | 71.48 | 14.54 |
| 30 | 1.150 | 17.15 | 20.98 | 0.2413 | 71.79 | 15.06 |
| 31 | 1.155 | 17.67 | 21.62 | 0.2497 | 72.11 | 15.59 |
| 32 | 1.160 | 18.19 | 22.26 | 0.2582 | 72.42 | 16.12 |
| 33 | 1.165 | 18.72 | 22.90 | 0.2668 | 72.73 | 16.66 |
| 34 | 1.170 | 19.24 | 23.54 | 0.2754 | 73.04 | 17.19 |
| 35 | 1.175 | 19.75 | 24.17 | 0.2840 | 73.35 | 17.73 |
| 36 | 1.180 | 20.27 | 24.80 | 0.2926 | 73.67 | 18.27 |
| 37 | 1.185 | 20.78 | 25.43 | 0.3013 | 73.98 | 18.81 |
| 38 | 1.190 | 21.29 | 26.05 | 0.3100 | 74.29 | 19.35 |
| 39 | 1.195 | 21.81 | 26.68 | 0.3188 | 74.60 | 19.90 |
| 40 | 1.200 | 22.31 | 27.30 | 0.3278 | 74.92 | 20.45 |
| 41 | 1.205 | 22.82 | 27.92 | 0.3364 | 75.23 | 21.00 |
| 42 | 1.210 | 23.17 | 28.53 | 0.3452 | 75.54 | 21.55 |
| 43 | 1.215 | 23.82 | 29.15 | 0.3542 | 75.85 | 22.11 |
| 44 | 1.220 | 24.32 | 29.76 | 0.3631 | 76.16 | 22.67 |
| 45 | 1.225 | 24.82 | 30.37 | 0.3720 | 76.48 | 23.23 |
| 46 | 1.230 | 25.32 | 30.98 | 0.3810 | 76.79 | 23.79 |

SPECIFIC GRAVITY OF SULPHURIC ACID—Continued.

| Degrees Twaddell. | Specific gravity d 15°/4°. | 100 parts by weight contain | | Kilos H ₂ SO ₄ per litre. | 1 Cubic foot of acid | |
|----------------------|----------------------------------|--------------------------------|----------------------------------|---|-----------------------|--|
| | | SO ₃ . | H ₂ SO ₄ . | | weighs lb. avoird. | contains lb. H ₂ SO ₄ . |
| 47 | 1.235 | 25.81 | 31.58 | 0.3900 | 77.10 | 24.35 |
| 48 | 1.240 | 26.30 | 32.18 | 0.3990 | 77.41 | 24.91 |
| 49 | 1.245 | 26.79 | 32.78 | 0.4081 | 77.72 | 25.48 |
| 50 | 1.250 | 27.28 | 33.38 | 0.4172 | 78.04 | 26.05 |
| 51 | 1.255 | 27.77 | 33.98 | 0.4264 | 78.35 | 26.62 |
| 52 | 1.260 | 28.25 | 34.57 | 0.4356 | 78.66 | 27.19 |
| 53 | 1.265 | 28.74 | 35.17 | 0.4449 | 78.97 | 27.77 |
| 54 | 1.270 | 29.23 | 35.76 | 0.4515 | 79.29 | 28.35 |
| 55 | 1.275 | 29.71 | 36.35 | 0.4635 | 79.60 | 28.93 |
| 56 | 1.280 | 30.19 | 36.94 | 0.4728 | 79.91 | 29.52 |
| 57 | 1.285 | 30.67 | 37.52 | 0.4821 | 80.22 | 30.10 |
| 58 | 1.290 | 31.14 | 38.10 | 0.4919 | 80.53 | 30.68 |
| 59 | 1.295 | 31.61 | 38.68 | 0.5009 | 80.85 | 31.27 |
| 60 | 1.300 | 32.08 | 39.25 | 0.5102 | 81.16 | 31.85 |
| 61 | 1.305 | 32.56 | 39.83 | 0.5198 | 81.47 | 32.45 |
| 62 | 1.310 | 33.02 | 40.40 | 0.5292 | 81.78 | 33.04 |
| 63 | 1.315 | 33.48 | 40.97 | 0.5388 | 82.09 | 33.63 |
| 64 | 1.320 | 33.94 | 41.53 | 0.5482 | 82.41 | 34.22 |
| 65 | 1.325 | 34.40 | 42.09 | 0.5577 | 82.72 | 34.82 |
| 66 | 1.330 | 34.86 | 42.65 | 0.5672 | 83.03 | 35.41 |
| 67 | 1.335 | 35.31 | 43.20 | 0.5767 | 83.34 | 36.00 |
| 68 | 1.340 | 35.76 | 43.75 | 0.5862 | 83.66 | 36.60 |
| 69 | 1.345 | 36.21 | 44.30 | 0.5958 | 83.97 | 37.20 |
| 70 | 1.350 | 36.66 | 44.85 | 0.6055 | 84.28 | 37.80 |
| 71 | 1.355 | 37.10 | 45.39 | 0.6150 | 84.59 | 38.40 |
| 72 | 1.360 | 37.54 | 45.93 | 0.6246 | 84.90 | 39.00 |
| 73 | 1.365 | 37.97 | 46.46 | 0.6342 | 85.22 | 39.59 |
| 74 | 1.370 | 38.40 | 46.99 | 0.6438 | 85.53 | 40.19 |
| 75 | 1.375 | 38.84 | 47.52 | 0.6534 | 85.84 | 40.79 |
| 76 | 1.380 | 39.26 | 48.04 | 0.6629 | 86.15 | 41.39 |
| 77 | 1.385 | 39.69 | 48.56 | 0.6726 | 86.47 | 41.99 |
| 78 | 1.390 | 40.10 | 49.07 | 0.6821 | 86.78 | 42.58 |
| 79 | 1.395 | 40.53 | 49.59 | 0.6918 | 87.09 | 43.19 |
| 80 | 1.400 | 40.95 | 50.10 | 0.7014 | 87.40 | 43.79 |
| 81 | 1.405 | 41.36 | 50.61 | 0.7111 | 87.71 | 44.39 |
| 82 | 1.410 | 41.78 | 51.12 | 0.7208 | 88.03 | 45.00 |
| 83 | 1.415 | 42.89 | 51.62 | 0.7304 | 88.34 | 45.60 |
| 84 | 1.420 | 42.60 | 52.12 | 0.7401 | 88.65 | 46.20 |
| 85 | 1.425 | 43.01 | 52.62 | 0.7498 | 88.96 | 46.81 |
| 86 | 1.430 | 43.41 | 53.11 | 0.7595 | 89.27 | 47.41 |
| 87 | 1.435 | 43.81 | 53.60 | 0.7692 | 89.59 | 48.02 |
| 88 | 1.440 | 44.21 | 54.09 | 0.7780 | 89.90 | 48.63 |
| 89 | 1.445 | 44.61 | 54.58 | 0.7887 | 90.21 | 49.24 |
| 90 | 1.450 | 45.00 | 55.06 | 0.7984 | 90.52 | 49.84 |
| 91 | 1.455 | 45.39 | 55.54 | 0.8081 | 90.84 | 50.45 |
| 92 | 1.460 | 45.79 | 56.02 | 0.8179 | 91.15 | 51.06 |

SPECIFIC GRAVITY OF SULPHURIC ACID—*Continued.*

| Degrees Twaddell. | Specific gravity <i>d</i> 15°/4°. | 100 parts by weight contain | | Kilos H ₂ SO ₄ per litre. | 1 Cubic foot of acid | |
|----------------------|---|--------------------------------|----------------------------------|---|-----------------------|--|
| | | SO ₃ . | H ₂ SO ₄ . | | weighs lb. avoird. | contains lb. H ₂ SO ₄ |
| 93 | 1·465 | 46·18 | 56·50 | 0·8277 | 91·46 | 51·67 |
| 94 | 1·470 | 46·56 | 56·97 | 0·8375 | 91·77 | 52·28 |
| 95 | 1·475 | 46·95 | 57·44 | 0·8472 | 92·08 | 52·89 |
| 96 | 1·480 | 47·33 | 57·91 | 0·8571 | 92·40 | 53·51 |
| 97 | 1·485 | 47·71 | 58·38 | 0·8669 | 92·71 | 54·12 |
| 98 | 1·490 | 48·10 | 58·85 | 0·8769 | 93·02 | 54·74 |
| 99 | 1·495 | 48·48 | 59·32 | 0·8868 | 93·33 | 55·36 |
| 100 | 1·500 | 48·86 | 59·78 | 0·8967 | 93·64 | 55·98 |
| 101 | 1·505 | 49·23 | 60·24 | 0·9066 | 93·96 | 56·60 |
| 102 | 1·510 | 49·61 | 60·70 | 0·9166 | 94·27 | 57·22 |
| 103 | 1·515 | 49·99 | 61·16 | 0·9266 | 94·58 | 57·85 |
| 104 | 1·520 | 50·35 | 61·61 | 0·9365 | 94·89 | 58·46 |
| 105 | 1·525 | 50·73 | 62·07 | 0·9466 | 95·21 | 59·09 |
| 106 | 1·530 | 51·10 | 62·52 | 0·9566 | 95·52 | 59·72 |
| 107 | 1·535 | 51·47 | 62·97 | 0·9666 | 95·83 | 60·34 |
| 108 | 1·540 | 51·83 | 63·42 | 0·9767 | 96·14 | 60·97 |
| 109 | 1·545 | 52·20 | 63·87 | 0·9868 | 96·45 | 61·60 |
| 110 | 1·550 | 52·56 | 64·31 | 0·9968 | 96·77 | 62·23 |
| 111 | 1·555 | 52·92 | 64·75 | 1·0069 | 97·08 | 62·86 |
| 112 | 1·560 | 53·28 | 65·19 | 1·0170 | 97·39 | 63·49 |
| 113 | 1·565 | 53·64 | 65·63 | 1·0271 | 97·70 | 64·12 |
| 114 | 1·570 | 54·01 | 66·08 | 1·0375 | 98·01 | 64·77 |
| 115 | 1·575 | 54·37 | 66·52 | 1·0477 | 98·33 | 65·41 |
| 116 | 1·580 | 54·73 | 66·96 | 1·0580 | 98·64 | 66·05 |
| 117 | 1·585 | 55·09 | 67·40 | 1·0683 | 98·95 | 66·69 |
| 118 | 1·590 | 55·44 | 67·83 | 1·0785 | 99·26 | 67·33 |
| 119 | 1·595 | 55·79 | 68·26 | 1·0887 | 99·58 | 67·97 |
| 120 | 1·600 | 56·14 | 68·69 | 1·0990 | 99·89 | 68·61 |
| 121 | 1·605 | 56·49 | 69·12 | 1·1094 | 100·20 | 69·26 |
| 122 | 1·610 | 56·84 | 69·55 | 1·1198 | 100·51 | 69·91 |
| 123 | 1·615 | 57·19 | 69·98 | 1·1302 | 100·82 | 70·56 |
| 124 | 1·620 | 57·46 | 70·41 | 1·1406 | 101·14 | 71·21 |
| 125 | 1·625 | 57·89 | 70·83 | 1·1510 | 101·45 | 71·86 |
| 126 | 1·630 | 58·25 | 71·27 | 1·1617 | 101·76 | 72·52 |
| 127 | 1·635 | 58·60 | 71·70 | 1·1723 | 102·07 | 73·19 |
| 128 | 1·640 | 58·95 | 72·13 | 1·1829 | 102·38 | 73·85 |
| 129 | 1·645 | 59·30 | 72·55 | 1·1934 | 102·70 | 74·51 |
| 130 | 1·650 | 59·64 | 72·97 | 1·2040 | 103·01 | 75·17 |
| 131 | 1·655 | 59·99 | 73·40 | 1·2148 | 103·32 | 75·84 |
| 132 | 1·660 | 60·33 | 73·82 | 1·2254 | 103·63 | 76·50 |
| 133 | 1·665 | 60·68 | 74·24 | 1·2361 | 103·95 | 77·17 |
| 134 | 1·670 | 61·02 | 74·66 | 1·2468 | 104·26 | 77·84 |
| 135 | 1·675 | 61·37 | 75·09 | 1·2578 | 104·57 | 78·52 |
| 136 | 1·680 | 61·71 | 75·51 | 1·2686 | 104·88 | 79·20 |
| 137 | 1·685 | 62·06 | 75·93 | 1·2794 | 105·19 | 79·87 |
| 138 | 1·690 | 62·41 | 76·36 | 1·2905 | 105·51 | 80·56 |

SPECIFIC GRAVITY OF SULPHURIC ACID—*Continued.*

| Degrees Twaddell. | Specific gravity at 15°/4°. | 100 parts by weight contain | | Kilos H ₂ SO ₄ per litre. | 1 Cubic foot of acid | |
|----------------------|-----------------------------------|--------------------------------|--------------------------------|---|----------------------|--|
| | | SO ₃ . | H ₂ SO ₄ | | weighs lb. avoiz. | contains lb. H ₂ SO ₄ . |
| 139 | 1·695 | 62·75 | 76·78 | 1·3014 | 105·82 | 81·25 |
| 140 | 1·700 | 63·10 | 77·21 | 1·3126 | 106·13 | 81·94 |
| 141 | 1·705 | 63·45 | 77·63 | 1·3236 | 106·44 | 82·63 |
| 142 | 1·710 | 63·80 | 78·06 | 1·3348 | 106·75 | 83·33 |
| 143 | 1·715 | 64·15 | 78·49 | 1·3461 | 107·07 | 84·04 |
| 144 | 1·720 | 64·50 | 78·92 | 1·3574 | 107·38 | 84·74 |
| 145 | 1·725 | 64·85 | 79·35 | 1·3688 | 107·69 | 85·45 |
| 146 | 1·730 | 65·21 | 79·79 | 1·3804 | 108·00 | 86·18 |
| 147 | 1·735 | 65·57 | 80·23 | 1·3920 | 108·32 | 86·90 |
| 148 | 1·740 | 65·94 | 80·68 | 1·4038 | 108·63 | 87·64 |
| 149 | 1·745 | 66·31 | 81·14 | 1·4159 | 108·94 | 88·39 |
| 150 | 1·750 | 66·69 | 81·60 | 1·4280 | 109·25 | 89·15 |
| 151 | 1·755 | 67·08 | 82·07 | 1·4403 | 109·56 | 89·92 |
| 152 | 1·760 | 67·46 | 82·54 | 1·4527 | 109·88 | 90·69 |
| 153 | 1·765 | 67·85 | 83·02 | 1·4653 | 110·19 | 91·48 |
| 154 | 1·770 | 68·24 | 83·50 | 1·4779 | 110·50 | 92·27 |
| 155 | 1·775 | 68·63 | 84·03 | 1·4915 | 110·81 | 93·12 |
| 156 | 1·780 | 69·11 | 84·56 | 1·5052 | 111·12 | 93·97 |
| 157 | 1·785 | 69·57 | 85·12 | 1·5194 | 111·44 | 94·86 |
| 158 | 1·790 | 70·03 | 85·69 | 1·5338 | 111·75 | 95·76 |
| 159 | 1·795 | 70·53 | 86·30 | 1·5491 | 112·06 | 96·71 |
| 160 | 1·800 | 71·04 | 86·92 | 1·5646 | 112·37 | 97·67 |
| 161 | 1·805 | 71·60 | 87·61 | 1·5814 | 112·69 | 98·72 |
| 162 | 1·810 | 72·21 | 88·35 | 1·5991 | 113·00 | 99·83 |
| 163 | 1·815 | 72·87 | 89·16 | 1·6182 | 113·310 | 101·03 |
| 164 | 1·820 | 73·59 | 90·04 | 1·6387 | 113·62 | 102·31 |

DENSITY OF SOLUTIONS CONTAINING ABOVE 90 PER CENT.
OF SULPHURIC ACID.

| Per cent. H ₂ SO ₄ | 91 | 92 | 93 | 94 | 95 |
|--|--------|--------|--------|--------|--------|
| Density d. $\frac{15^\circ}{4^\circ}$ | 1·8248 | 1·8293 | 1·8331 | 1·8363 | 1·8388 |
| Per cent. H ₂ SO ₄ | 96 | 97 | 98 | 99 | 100 |
| Density d. $\frac{15^\circ}{4^\circ}$ | 1·8406 | 1·8466 | 1·8411 | 1·8393 | 1·8357 |

150 THE TECHNICAL CHEMISTS' HANDBOOK

**2. TABLE FOR REDUCING THE SPECIFIC GRAVITIES OF
SULPHURIC ACID OF VARIOUS STRENGTHS TO ANY
OTHER TEMPERATURE (DEGREES C.).**

| 0°. | 5°. | 10°. | 15°. | 20°. | 25°. | 30°. | 35°. | 40°. | 45°. | 50°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·857 | 1·852 | 1·846 | 1·840 | 1·835 | 1·830 | 1·825 | 1·821 | 1·816 | 1·811 | 1·806 |
| 1·847 | 1·841 | 1·836 | 1·830 | 1·825 | 1·820 | 1·815 | 1·810 | 1·805 | 1·800 | 1·795 |
| 1·837 | 1·831 | 1·825 | 1·820 | 1·815 | 1·809 | 1·804 | 1·799 | 1·794 | 1·789 | 1·784 |
| 1·827 | 1·821 | 1·815 | 1·810 | 1·805 | 1·799 | 1·793 | 1·788 | 1·783 | 1·778 | 1·773 |
| 1·817 | 1·811 | 1·805 | 1·800 | 1·794 | 1·788 | 1·783 | 1·777 | 1·772 | 1·766 | 1·761 |
| 1·807 | 1·801 | 1·796 | 1·790 | 1·784 | 1·778 | 1·773 | 1·767 | 1·762 | 1·756 | 1·751 |
| 1·797 | 1·791 | 1·786 | 1·780 | 1·774 | 1·768 | 1·763 | 1·757 | 1·752 | 1·746 | 1·741 |
| 1·786 | 1·781 | 1·776 | 1·770 | 1·765 | 1·759 | 1·754 | 1·748 | 1·743 | 1·737 | 1·732 |
| 1·776 | 1·770 | 1·765 | 1·760 | 1·755 | 1·749 | 1·744 | 1·738 | 1·733 | 1·728 | 1·723 |
| 1·765 | 1·760 | 1·755 | 1·750 | 1·745 | 1·740 | 1·735 | 1·730 | 1·725 | 1·720 | 1·715 |
| 1·754 | 1·750 | 1·745 | 1·740 | 1·735 | 1·730 | 1·726 | 1·721 | 1·716 | 1·711 | 1·706 |
| 1·744 | 1·740 | 1·735 | 1·730 | 1·725 | 1·720 | 1·716 | 1·711 | 1·706 | 1·701 | 1·696 |
| 1·734 | 1·730 | 1·725 | 1·720 | 1·715 | 1·710 | 1·706 | 1·701 | 1·696 | 1·691 | 1·686 |
| 1·724 | 1·720 | 1·715 | 1·710 | 1·705 | 1·700 | 1·696 | 1·691 | 1·686 | 1·681 | 1·676 |
| 1·714 | 1·710 | 1·705 | 1·700 | 1·695 | 1·690 | 1·686 | 1·681 | 1·676 | 1·671 | 1·667 |
| 1·704 | 1·700 | 1·695 | 1·690 | 1·685 | 1·680 | 1·676 | 1·671 | 1·666 | 1·661 | 1·656 |
| 1·694 | 1·690 | 1·685 | 1·680 | 1·675 | 1·670 | 1·666 | 1·661 | 1·656 | 1·651 | 1·646 |
| 1·684 | 1·680 | 1·675 | 1·670 | 1·665 | 1·660 | 1·656 | 1·651 | 1·646 | 1·641 | 1·637 |
| 1·674 | 1·670 | 1·665 | 1·660 | 1·655 | 1·650 | 1·646 | 1·641 | 1·636 | 1·632 | 1·628 |
| 1·664 | 1·660 | 1·655 | 1·650 | 1·645 | 1·640 | 1·636 | 1·632 | 1·627 | 1·622 | 1·618 |
| 1·654 | 1·650 | 1·645 | 1·640 | 1·635 | 1·631 | 1·626 | 1·622 | 1·617 | 1·612 | 1·608 |
| 1·644 | 1·640 | 1·635 | 1·630 | 1·625 | 1·621 | 1·616 | 1·612 | 1·607 | 1·602 | 1·598 |
| 1·634 | 1·630 | 1·625 | 1·620 | 1·615 | 1·611 | 1·606 | 1·602 | 1·597 | 1·592 | 1·588 |
| 1·624 | 1·620 | 1·615 | 1·610 | 1·605 | 1·601 | 1·596 | 1·592 | 1·587 | 1·582 | 1·578 |
| 1·614 | 1·610 | 1·605 | 1·600 | 1·595 | 1·591 | 1·586 | 1·582 | 1·577 | 1·572 | 1·568 |
| 1·604 | 1·600 | 1·595 | 1·590 | 1·585 | 1·581 | 1·576 | 1·572 | 1·567 | 1·562 | 1·558 |
| 1·594 | 1·589 | 1·584 | 1·580 | 1·575 | 1·570 | 1·566 | 1·562 | 1·558 | 1·553 | 1·548 |
| 1·584 | 1·579 | 1·574 | 1·570 | 1·566 | 1·561 | 1·556 | 1·552 | 1·548 | 1·543 | 1·539 |
| 1·574 | 1·569 | 1·564 | 1·560 | 1·556 | 1·552 | 1·547 | 1·543 | 1·539 | 1·534 | 1·530 |
| 1·563 | 1·558 | 1·554 | 1·550 | 1·546 | 1·542 | 1·538 | 1·534 | 1·530 | 1·525 | 1·521 |
| 1·552 | 1·548 | 1·544 | 1·540 | 1·536 | 1·532 | 1·528 | 1·524 | 1·520 | 1·516 | 1·512 |
| 1·542 | 1·538 | 1·534 | 1·530 | 1·526 | 1·522 | 1·518 | 1·514 | 1·510 | 1·506 | 1·502 |
| 1·532 | 1·528 | 1·524 | 1·520 | 1·516 | 1·512 | 1·508 | 1·504 | 1·500 | 1·497 | 1·492 |
| 1·522 | 1·518 | 1·514 | 1·510 | 1·506 | 1·502 | 1·498 | 1·494 | 1·490 | 1·486 | 1·482 |
| 1·512 | 1·508 | 1·504 | 1·500 | 1·496 | 1·492 | 1·488 | 1·484 | 1·480 | 1·476 | 1·472 |
| 1·502 | 1·498 | 1·494 | 1·490 | 1·486 | 1·482 | 1·478 | 1·474 | 1·470 | 1·466 | 1·462 |
| 1·492 | 1·488 | 1·484 | 1·480 | 1·476 | 1·472 | 1·468 | 1·465 | 1·461 | 1·457 | 1·453 |
| 1·482 | 1·478 | 1·474 | 1·470 | 1·466 | 1·462 | 1·458 | 1·455 | 1·451 | 1·447 | 1·443 |
| 1·472 | 1·468 | 1·464 | 1·460 | 1·456 | 1·452 | 1·448 | 1·445 | 1·442 | 1·438 | 1·434 |
| 1·462 | 1·458 | 1·454 | 1·450 | 1·446 | 1·442 | 1·438 | 1·435 | 1·432 | 1·429 | 1·425 |
| 1·452 | 1·448 | 1·444 | 1·440 | 1·436 | 1·432 | 1·429 | 1·426 | 1·423 | 1·420 | 1·416 |
| 1·442 | 1·438 | 1·434 | 1·430 | 1·426 | 1·422 | 1·419 | 1·416 | 1·413 | 1·409 | 1·405 |
| 1·432 | 1·428 | 1·424 | 1·420 | 1·416 | 1·413 | 1·410 | 1·406 | 1·402 | 1·398 | 1·394 |
| 1·422 | 1·418 | 1·414 | 1·410 | 1·406 | 1·403 | 1·399 | 1·396 | 1·392 | 1·388 | 1·384 |
| 1·412 | 1·408 | 1·404 | 1·400 | 1·396 | 1·393 | 1·389 | 1·386 | 1·382 | 1·378 | 1·374 |
| 1·402 | 1·398 | 1·394 | 1·390 | 1·386 | 1·383 | 1·379 | 1·375 | 1·372 | 1·368 | 1·364 |
| 1·392 | 1·388 | 1·384 | 1·380 | 1·376 | 1·373 | 1·370 | 1·366 | 1·362 | 1·359 | 1·355 |
| 1·382 | 1·378 | 1·374 | 1·370 | 1·366 | 1·363 | 1·360 | 1·356 | 1·352 | 1·349 | 1·346 |
| 1·372 | 1·368 | 1·364 | 1·360 | 1·356 | 1·353 | 1·350 | 1·347 | 1·344 | 1·340 | 1·336 |
| 1·362 | 1·358 | 1·354 | 1·350 | 1·346 | 1·343 | 1·340 | 1·337 | 1·334 | 1·330 | 1·326 |

TABLE 2—Continued.

| 55°. | 60°. | 65°. | 70°. | 75°. | 80°. | 85°. | 90°. | 95°. | 100°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·801 | 1·796 | 1·792 | 1·787 | 1·782 | 1·778 | 1·774 | 1·770 | 1·766 | 1·762 |
| 1·790 | 1·787 | 1·781 | 1·776 | 1·770 | 1·766 | 1·762 | 1·757 | 1·752 | 1·748 |
| 1·779 | 1·774 | 1·769 | 1·764 | 1·759 | 1·754 | 1·749 | 1·744 | 1·739 | 1·734 |
| 1·767 | 1·762 | 1·757 | 1·752 | 1·747 | 1·741 | 1·736 | 1·731 | 1·726 | 1·721 |
| 1·755 | 1·750 | 1·744 | 1·739 | 1·734 | 1·729 | 1·724 | 1·719 | 1·714 | 1·708 |
| 1·746 | 1·741 | 1·735 | 1·730 | 1·725 | 1·720 | 1·715 | 1·710 | 1·705 | 1·700 |
| 1·736 | 1·731 | 1·726 | 1·721 | 1·716 | 1·712 | 1·707 | 1·702 | 1·697 | 1·692 |
| 1·727 | 1·722 | 1·717 | 1·712 | 1·707 | 1·702 | 1·697 | 1·693 | 1·688 | 1·683 |
| 1·718 | 1·713 | 1·708 | 1·703 | 1·698 | 1·693 | 1·688 | 1·684 | 1·679 | 1·674 |
| 1·710 | 1·705 | 1·700 | 1·695 | 1·690 | 1·685 | 1·681 | 1·676 | 1·671 | 1·667 |
| 1·702 | 1·697 | 1·692 | 1·688 | 1·683 | 1·678 | 1·674 | 1·669 | 1·664 | 1·660 |
| 1·692 | 1·687 | 1·683 | 1·678 | 1·673 | 1·668 | 1·664 | 1·659 | 1·654 | 1·650 |
| 1·682 | 1·677 | 1·673 | 1·668 | 1·663 | 1·659 | 1·654 | 1·649 | 1·644 | 1·640 |
| 1·672 | 1·667 | 1·663 | 1·658 | 1·653 | 1·649 | 1·644 | 1·639 | 1·635 | 1·630 |
| 1·662 | 1·657 | 1·653 | 1·648 | 1·644 | 1·639 | 1·634 | 1·630 | 1·625 | 1·620 |
| 1·652 | 1·647 | 1·642 | 1·638 | 1·634 | 1·630 | 1·625 | 1·620 | 1·615 | 1·610 |
| 1·642 | 1·637 | 1·632 | 1·628 | 1·624 | 1·620 | 1·615 | 1·611 | 1·606 | 1·602 |
| 1·633 | 1·628 | 1·623 | 1·619 | 1·615 | 1·611 | 1·606 | 1·602 | 1·597 | 1·593 |
| 1·623 | 1·619 | 1·614 | 1·610 | 1·606 | 1·602 | 1·597 | 1·593 | 1·588 | 1·584 |
| 1·614 | 1·610 | 1·605 | 1·600 | 1·596 | 1·592 | 1·588 | 1·583 | 1·579 | 1·575 |
| 1·604 | 1·600 | 1·595 | 1·591 | 1·586 | 1·582 | 1·578 | 1·574 | 1·570 | 1·565 |
| 1·594 | 1·590 | 1·585 | 1·581 | 1·577 | 1·573 | 1·569 | 1·565 | 1·561 | 1·556 |
| 1·584 | 1·580 | 1·576 | 1·572 | 1·568 | 1·564 | 1·560 | 1·556 | 1·552 | 1·547 |
| 1·574 | 1·570 | 1·566 | 1·562 | 1·558 | 1·554 | 1·550 | 1·546 | 1·542 | 1·537 |
| 1·564 | 1·560 | 1·556 | 1·552 | 1·548 | 1·544 | 1·540 | 1·536 | 1·531 | 1·527 |
| 1·554 | 1·550 | 1·545 | 1·541 | 1·537 | 1·533 | 1·529 | 1·525 | 1·521 | 1·516 |
| 1·544 | 1·539 | 1·535 | 1·531 | 1·527 | 1·523 | 1·519 | 1·515 | 1·510 | 1·506 |
| 1·535 | 1·531 | 1·526 | 1·522 | 1·518 | 1·513 | 1·509 | 1·505 | 1·501 | 1·496 |
| 1·526 | 1·522 | 1·517 | 1·513 | 1·509 | 1·504 | 1·500 | 1·496 | 1·492 | 1·487 |
| 1·517 | 1·513 | 1·509 | 1·504 | 1·500 | 1·495 | 1·491 | 1·487 | 1·483 | 1·478 |
| 1·508 | 1·504 | 1·500 | 1·495 | 1·491 | 1·486 | 1·482 | 1·478 | 1·473 | 1·469 |
| 1·498 | 1·494 | 1·490 | 1·485 | 1·481 | 1·476 | 1·472 | 1·468 | 1·463 | 1·459 |
| 1·488 | 1·484 | 1·480 | 1·476 | 1·472 | 1·467 | 1·462 | 1·458 | 1·453 | 1·449 |
| 1·478 | 1·474 | 1·470 | 1·466 | 1·462 | 1·457 | 1·452 | 1·448 | 1·443 | 1·438 |
| 1·468 | 1·464 | 1·460 | 1·455 | 1·451 | 1·446 | 1·442 | 1·438 | 1·433 | 1·428 |
| 1·458 | 1·454 | 1·450 | 1·442 | 1·441 | 1·437 | 1·433 | 1·429 | 1·424 | 1·419 |
| 1·449 | 1·445 | 1·441 | 1·436 | 1·432 | 1·428 | 1·424 | 1·419 | 1·414 | 1·410 |
| 1·439 | 1·435 | 1·431 | 1·427 | 1·423 | 1·418 | 1·414 | 1·409 | 1·405 | 1·401 |
| 1·430 | 1·426 | 1·422 | 1·418 | 1·413 | 1·409 | 1·405 | 1·400 | 1·396 | 1·392 |
| 1·421 | 1·417 | 1·413 | 1·409 | 1·404 | 1·400 | 1·396 | 1·391 | 1·387 | 1·383 |
| 1·412 | 1·407 | 1·403 | 1·399 | 1·395 | 1·391 | 1·386 | 1·382 | 1·378 | 1·374 |
| 1·401 | 1·397 | 1·393 | 1·389 | 1·385 | 1·380 | 1·376 | 1·372 | 1·368 | 1·364 |
| 1·390 | 1·386 | 1·382 | 1·378 | 1·374 | 1·370 | 1·366 | 1·362 | 1·358 | 1·353 |
| 1·380 | 1·376 | 1·372 | 1·368 | 1·364 | 1·360 | 1·356 | 1·352 | 1·348 | 1·343 |
| 1·370 | 1·366 | 1·362 | 1·358 | 1·354 | 1·350 | 1·346 | 1·342 | 1·338 | 1·333 |
| 1·360 | 1·356 | 1·352 | 1·348 | .. | .. | .. | .. | .. | .. |
| 1·351 | 1·346 | 1·342 | 1·338 | .. | .. | .. | .. | .. | .. |
| 1·342 | 1·337 | 1·334 | 1·329 | .. | .. | .. | .. | .. | .. |
| 1·332 | 1·327 | 1·323 | 1·319 | .. | .. | .. | .. | .. | .. |
| 1·322 | 1·317 | 1·314 | 1·310 | .. | .. | .. | .. | .. | .. |

TABLE 2—Continued.

| 0°. | 5°. | 10°. | 15°. | 20°. | 25°. | 30°. | 35°. | 40°. | 45°. | 50°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·352 | 1·348 | 1·344 | 1·340 | 1·336 | 1·333 | 1·330 | 1·327 | 1·324 | 1·320 | 1·316 |
| 1·341 | 1·337 | 1·333 | 1·330 | 1·327 | 1·324 | 1·321 | 1·318 | 1·314 | 1·310 | 1·306 |
| 1·330 | 1·326 | 1·323 | 1·320 | 1·317 | 1·314 | 1·311 | 1·308 | 1·304 | 1·301 | 1·297 |
| 1·320 | 1·316 | 1·313 | 1·310 | 1·307 | 1·304 | 1·301 | 1·298 | 1·294 | 1·291 | 1·287 |
| 1·310 | 1·306 | 1·303 | 1·300 | 1·297 | 1·294 | 1·291 | 1·288 | 1·284 | 1·281 | 1·277 |
| 1·300 | 1·296 | 1·293 | 1·290 | 1·287 | 1·284 | 1·280 | 1·277 | 1·274 | 1·270 | 1·267 |
| 1·290 | 1·286 | 1·283 | 1·280 | 1·277 | 1·274 | 1·270 | 1·267 | 1·264 | 1·260 | 1·256 |
| 1·280 | 1·276 | 1·273 | 1·270 | 1·267 | 1·264 | 1·260 | 1·257 | 1·254 | 1·250 | 1·246 |
| 1·270 | 1·266 | 1·263 | 1·260 | 1·257 | 1·254 | 1·251 | 1·248 | 1·245 | 1·241 | 1·237 |
| 1·260 | 1·256 | 1·253 | 1·250 | 1·247 | 1·244 | 1·241 | 1·238 | 1·235 | 1·231 | 1·227 |
| 1·250 | 1·246 | 1·243 | 1·240 | 1·237 | 1·234 | 1·230 | 1·227 | 1·224 | 1·220 | 1·217 |
| 1·240 | 1·236 | 1·233 | 1·230 | 1·227 | 1·224 | 1·220 | 1·217 | 1·214 | 1·210 | 1·207 |
| 1·230 | 1·226 | 1·223 | 1·220 | 1·217 | 1·214 | 1·210 | 1·207 | 1·204 | 1·200 | 1·197 |
| 1·220 | 1·216 | 1·213 | 1·210 | 1·206 | 1·201 | 1·200 | 1·197 | 1·194 | 1·190 | 1·187 |
| 1·210 | 1·206 | 1·203 | 1·200 | 1·196 | 1·193 | 1·190 | 1·186 | 1·183 | 1·180 | 1·176 |
| 1·200 | 1·196 | 1·193 | 1·190 | 1·186 | 1·183 | 1·180 | 1·176 | 1·173 | 1·169 | 1·165 |
| 1·190 | 1·186 | 1·183 | 1·180 | 1·176 | 1·173 | 1·170 | 1·166 | 1·163 | 1·159 | 1·155 |
| 1·180 | 1·176 | 1·173 | 1·170 | 1·166 | 1·163 | 1·160 | 1·156 | 1·153 | 1·149 | 1·146 |
| 1·169 | 1·166 | 1·163 | 1·160 | 1·157 | 1·153 | 1·150 | 1·147 | 1·144 | 1·141 | 1·138 |
| 1·159 | 1·156 | 1·153 | 1·150 | 1·147 | 1·143 | 1·140 | 1·137 | 1·134 | 1·131 | 1·128 |
| 1·149 | 1·146 | 1·143 | 1·140 | 1·137 | 1·134 | 1·131 | 1·128 | 1·125 | 1·122 | 1·119 |
| 1·138 | 1·135 | 1·133 | 1·130 | 1·127 | 1·125 | 1·122 | 1·119 | 1·116 | 1·113 | 1·110 |
| 1·128 | 1·125 | 1·123 | 1·120 | 1·118 | 1·115 | 1·112 | 1·110 | 1·107 | 1·104 | 1·102 |
| 1·118 | 1·115 | 1·113 | 1·110 | 1·108 | 1·105 | 1·102 | 1·100 | 1·097 | 1·094 | 1·092 |
| 1·108 | 1·105 | 1·103 | 1·100 | 1·097 | 1·094 | 1·092 | 1·090 | 1·087 | 1·084 | 1·082 |
| 1·098 | 1·095 | 1·093 | 1·090 | 1·087 | 1·084 | 1·082 | 1·080 | 1·077 | 1·074 | 1·072 |
| 1·088 | 1·085 | 1·083 | 1·080 | 1·077 | 1·074 | 1·072 | 1·070 | 1·067 | 1·064 | 1·062 |
| 1·078 | 1·075 | 1·073 | 1·070 | 1·067 | 1·064 | 1·062 | 1·060 | 1·057 | 1·054 | 1·052 |
| 1·068 | 1·065 | 1·063 | 1·060 | 1·057 | 1·054 | 1·052 | 1·050 | 1·048 | 1·044 | 1·042 |
| 1·058 | 1·055 | 1·053 | 1·050 | 1·047 | 1·044 | 1·042 | 1·040 | 1·038 | 1·034 | 1·032 |
| 1·048 | 1·045 | 1·043 | 1·040 | 1·037 | 1·034 | 1·032 | 1·030 | 1·028 | 1·024 | 1·022 |
| 1·038 | 1·035 | 1·033 | 1·030 | 1·027 | 1·024 | 1·022 | 1·020 | 1·018 | 1·014 | 1·012 |
| 1·028 | 1·025 | 1·023 | 1·020 | 1·017 | 1·014 | 1·012 | 1·010 | 1·008 | 1·004 | 1·002 |
| 1·018 | 1·015 | 1·013 | 1·010 | 1·007 | 1·004 | 1·002 | 1·000 | 0·998 | 0·994 | 0·992 |

TABLE 2—Continued.

| 55°. | 60°. | 65°. | 70°. | 75°. | 80°. | 85°. | 90°. | 95°. | 100°. |
|-------|-------|-------|-------|------|------|------|------|------|-------|
| 1·812 | 1·808 | 1·804 | 1·800 | .. | .. | .. | .. | .. | .. |
| 1·802 | 1·298 | 1·294 | 1·290 | .. | .. | .. | .. | .. | .. |
| 1·298 | 1·289 | 1·284 | 1·280 | .. | .. | .. | .. | .. | .. |
| 1·283 | 1·279 | 1·274 | 1·270 | .. | .. | .. | .. | .. | .. |
| 1·273 | 1·269 | 1·265 | 1·260 | .. | .. | .. | .. | .. | .. |
| 1·263 | 1·259 | 1·255 | 1·250 | .. | .. | .. | .. | .. | .. |
| 1·252 | 1·248 | 1·244 | 1·240 | .. | .. | .. | .. | .. | .. |
| 1·242 | 1·238 | 1·234 | 1·230 | .. | .. | .. | .. | .. | .. |
| 1·233 | 1·228 | 1·224 | 1·220 | .. | .. | .. | .. | .. | .. |
| 1·223 | 1·218 | 1·214 | 1·210 | .. | .. | .. | .. | .. | .. |
| 1·210 | 1·209 | 1·204 | 1·200 | .. | .. | .. | .. | .. | .. |
| 1·204 | 1·200 | 1·195 | 1·190 | .. | .. | .. | .. | .. | .. |
| 1·194 | 1·190 | 1·185 | 1·180 | .. | .. | .. | .. | .. | .. |
| 1·183 | 1·179 | 1·175 | 1·170 | .. | .. | .. | .. | .. | .. |
| 1·172 | 1·168 | 1·164 | 1·160 | .. | .. | .. | .. | .. | .. |
| 1·162 | 1·158 | 1·154 | 1·150 | .. | .. | .. | .. | .. | .. |
| 1·152 | 1·148 | 1·144 | 1·140 | .. | .. | .. | .. | .. | .. |
| 1·143 | 1·139 | 1·135 | 1·131 | .. | .. | .. | .. | .. | .. |
| 1·135 | 1·131 | 1·127 | 1·123 | .. | .. | .. | .. | .. | .. |
| 1·125 | 1·122 | 1·118 | 1·114 | .. | .. | .. | .. | .. | .. |
| 1·116 | 1·113 | 1·109 | 1·106 | .. | .. | .. | .. | .. | .. |
| 1·107 | 1·104 | 1·100 | 1·097 | .. | .. | .. | .. | .. | .. |
| 1·099 | 1·096 | 1·092 | 1·088 | .. | .. | .. | .. | .. | .. |
| 1·089 | 1·086 | 1·082 | 1·078 | .. | .. | .. | .. | .. | .. |
| 1·079 | 1·075 | 1·072 | 1·068 | .. | .. | .. | .. | .. | .. |
| 1·069 | 1·065 | 1·062 | 1·058 | .. | .. | .. | .. | .. | .. |
| 1·059 | 1·055 | 1·052 | 1·048 | .. | .. | .. | .. | .. | .. |
| 1·049 | 1·045 | 1·042 | 1·038 | .. | .. | .. | .. | .. | .. |
| 1·036 | 1·035 | 1·032 | 1·028 | .. | .. | .. | .. | .. | .. |
| 1·039 | 1·025 | 1·022 | 1·018 | .. | .. | .. | .. | .. | .. |
| 1·019 | 1·015 | 1·012 | 1·008 | .. | .. | .. | .. | .. | .. |
| 1·009 | 1·005 | 1·002 | 0·998 | .. | .. | .. | .. | .. | .. |
| 0·999 | 0·995 | 0·992 | 0·988 | .. | .. | .. | .. | .. | .. |
| 0·989 | 0·985 | 0·982 | 0·978 | .. | .. | .. | .. | .. | .. |

3. SPECIFIC GRAVITIES OF COMMERCIAL (NORDHAUSEN) OIL OF VITRIOL.

(Messel, *Journ. Soc. Chem. Ind.*, 1885, p. 573.)

| Specimens. | Percentage of SO_3 . | Specific Gravity. | |
|--------------------------------------|----------------------------------|---|---|
| | | At 80°F. $= 26.6^\circ \text{C.}$ | At 60°F. $= 15.5^\circ \text{C.}$ |
| Liquid | 8.3 | 1.842 | 1.852 |
| Do. | 30.0 | 1.930 | 1.940 |
| Crystalline mass, resembling nitre . | 40.0 | 1.956 | 1.970 |
| Do. do. | 44.5 | 1.961 | 1.975 |
| Do. do. | 46.2 | 1.963 | 1.977 |
| ... | 59.4 | 1.980 | 1.994 |
| Liquid | 60.8 | 1.992 | 2.006 |
| Do. | 65.0 | 1.992 | 2.006 |
| Do. | 69.4 | 2.002 | 2.016 |
| Crystallised | 72.8 | 1.984 | 1.988 |
| Do. | 80.0 | 1.959 | 1.973 |
| Do. | 82.0 | 1.953 | 1.967 |

4. FREEZING AND MELTING POINTS OF SULPHURIC ACID.*

| Specific Gravity at 15° . | Freezing Point. | Melting Point. |
|----------------------------------|-----------------------|----------------|
| 1.671 | Liquid at -20° | ... |
| 1.691 | Liquid at -20° | ... |
| 1.712 | Liquid at -20° | ... |
| 1.727 | -7.5° | -7.5° |
| 1.732 | -8.5° | -8.5° |
| 1.749 | -0.2° | $+4.5^\circ$ |
| 1.767 | $+1.6^\circ$ | $+6.5^\circ$ |
| 1.778 | $+8.5^\circ$ | $+8.5^\circ$ |
| 1.790 | $+4.5^\circ$ | $+8.0^\circ$ |
| 1.807 | -9.0° | -6.0° |
| 1.822 | Liquid at -20° | ... |
| 1.840 | Liquid at -20° | ... |

* Lunge, *Berichte d. deutsch. chem. Ges.*, 1881, s. 2649.

5. BOILING POINTS OF SULPHURIC ACID.

(Lunge, *Ber. d. d. chem. Ges.*, 11, 370.)

| Per Cent. H ₂ SO ₄ . | Specific Gravity. | Boiling Point. | Per Cent. H ₂ SO ₄ . | Specific Gravity. | Boiling Point. | Per Cent. H ₂ SO ₄ . | Specific Gravity. | Boiling Point. |
|---|-------------------|----------------|---|-------------------|----------------|---|-------------------|----------------|
| | | Degrees. | | | Degrees. | | | Degrees. |
| 5 | 1·031 | 101 | 56 | 1·459 | 133 | 82 | 1·758 | 218·5 |
| 10 | 1·069 | 102 | 60 | 1·503 | 141·5 | 84 | 1·773 | 227 |
| 15 | 1·107 | 103·5 | 62·5 | 1·530 | 147 | 86 | 1·791 | 238·5 |
| 20 | 1·147 | 105 | 65 | 1·557 | 153·5 | 88 | 1·807 | 251·5 |
| 25 | 1·184 | 106·5 | 67·5 | 1·585 | 161 | 90 | 1·818 | 262·5 |
| 30 | 1·224 | 108 | 70 | 1·615 | 170 | 91 | 1·824 | 268 |
| 35 | 1·265 | 110 | 72 | 1·639 | 174·5 | 92 | 1·830 | 274·5 |
| 40 | 1·307 | 114 | 74 | 1·661 | 180·5 | 93 | 1·834 | 281·5 |
| 45 | 1·352 | 118·5 | 76 | 1·688 | 189 | 94 | 1·837 | 288·5 |
| 50 | 1·399 | 124 | 78 | 1·710 | 199 | 95 | 1·840 | 295 |
| 53 | 1·428 | 128·5 | 80 | 1·733 | 207 | | | |

Monohydrate (100 per cent.) boils at 338° (Marignac).

6. BOILING POINTS OF OLEUM (FUMING SULPHURIC ACID).

| Per cent. free SO ₃ . | Per cent. total SO ₃ . | Boiling Point °C. | Barometric Pressure, mm. |
|-------------------------------------|--------------------------------------|----------------------|-----------------------------|
| 3·64 | 82·3 | 212 | 759 |
| 9·63 | 83·4 | 170 | 759 |
| 26·23 | 86·45 | 125 | 759 |
| 42·84 | 89·5 | 92 | 759 |
| 63·20 | 93·24 | 60 | 759 |
| 97·2 | 99·5 | 43 | 759 |

7. TOTAL VAPOUR PRESSURE OF SULPHURIC

[illegible]

8. SPECIFIC GRAVITIES AND PERCENTAGE OF FUMING OIL OF VITRIOL (OLEUM) AT DIFFERENT TEMPERATURES.

| Density at | | | | | SO ₃ Per Cent. |
|------------|--------|--------|--------|--------|------------------------------|
| 15°. | 20°. | 25°. | 30°. | 35°. | |
| 1·8417 | 1·8371 | 1·8323 | 1·8287 | 1·8240 | 76·67 |
| 1·8427 | 1·8378 | 1·8333 | 1·8295 | 1·8249 | 77·49 |
| 1·8428 | 1·8388 | 1·8351 | 1·8302 | 1·8255 | 78·34 |
| 1·8437 | 1·8390 | 1·8346 | 1·8300 | 1·8257 | 79·04 |
| 1·8427 | 1·8386 | 1·8351 | 1·8297 | 1·8250 | 79·99 |
| 1·8420 | 1·8372 | 1·8326 | 1·8281 | 1·8234 | 80·46 |
| 1·8398 | 1·8350 | 1·8305 | 1·8263 | 1·8218 | 80·94 |
| 1·8446 | 1·8400 | 1·8353 | 1·8307 | 1·8262 | 81·37 |
| 1·8509 | 1·8466 | 1·8418 | 1·8371 | 1·8324 | 81·91 |
| 1·8571 | 1·8522 | 1·8476 | 1·8432 | 1·8385 | 82·17 |
| 1·8697 | 1·8647 | 1·8595 | 1·8545 | 1·8498 | 82·94 |
| 1·8790 | 1·8742 | 1·8687 | 1·8640 | 1·8592 | 83·25 |
| 1·8875 | 1·8823 | 1·8767 | 1·8713 | 1·8661 | 83·84 |
| 1·8942 | 1·8888 | 1·8833 | 1·8775 | 1·8722 | 84·12 |
| 1·8990 | 1·8940 | 1·8890 | 1·8830 | 1·8772 | 84·33 |
| 1·9034 | 1·8984 | 1·8930 | 1·8874 | 1·8820 | 84·67 |
| 1·9072 | 1·9021 | 1·8950 | 1·8900 | 1·8845 | 84·82 |
| 1·9095 | 1·9042 | 1·8986 | 1·8932 | 1·8866 | 84·99 |
| 1·9121 | 1·9053 | 1·8993 | 1·8948 | 1·8892 | 85·14 |
| 1·9250 | 1·9193 | 1·9135 | 1·9082 | 1·9023 | 85·54 |
| 1·9290 | 1·9236 | 1·9183 | 1·9129 | 1·9073 | 85·68 |
| 1·9368 | 1·9310 | 1·9250 | 1·9187 | 1·9122 | 85·88 |
| 1·9447 | 1·9392 | 1·9334 | 1·9279 | 1·9222 | 86·51 |
| 1·9520 | 1·9465 | 1·9402 | 1·9338 | 1·9278 | 86·72 |
| 1·9584 | 1·9528 | 1·9466 | 1·9406 | 1·9340 | 87·03 |
| 1·9632 | 1·9573 | 1·9518 | 1·9457 | 1·9398 | 87·46 |
| cryst. | cryst. | 1·9740 | 1·9666 | 1·9740 | 88·00 |

The above table is only intended for control in works, but not for commercial purposes, because the specific gravity is anything but a certain guide for the percentage of Nordhausen acid, and altogether fails as such, for strengths just below the monohydrate. The table was not made for chemically pure acids, but for commercial acid.

**9. FUSING POINTS* OF SULPHURIC ACID AND OF
NORDHAUSEN OIL OF VITRIOL. (KNIETSCH.)**

| Sulphuric Acid. | | | | Nordhausen Oil of Vitriol. | |
|---|-------------------|---|-------------------|--------------------------------------|-------------------|
| Percentage of SO ₃ (as H ₂ SO ₄). | Fusing Point. °C. | Percentage of SO ₃ (as H ₂ SO ₄). | Fusing Point. °C. | Percentage of free SO ₃ . | Fusing Point. °C. |
| Per cent. | | Per cent. | | Per cent. | |
| 1 SO ₃ | - 0·6 | 69 SO ₃ | + 7·0 | 0 SO ₃ | + 10·0 |
| 2 " | - 1·0 | 70 " | + 4·0 | 5 " | + 3·5 |
| 3 " | - 1·7 | 71 " | - 1·0 | 10 " | - 4·8 |
| 4 " | - 2·0 | 72 " | - 2·0 | 15 " | - 11·2 |
| 5 " | - 2·7 | 73 " | - 16·2 | 20 " | - 11·0 |
| 6 " | - 3·6 | 74 " | - 25·0 | 25 " | - 0·6 |
| 7 " | - 4·4 | 75 " | - 34·0 | 30 " | + 15·2 |
| 8 " | - 5·3 | 76 " | - 32·0 | 35 " | + 26·0 |
| 9 " | - 6·0 | 77 " | - 33·0 | 40 " | + 33·8 |
| 10 " | - 6·7 | 78 " | - 16·5 | 45 " | + 34·8 |
| 11 " | - 7·2 | 79 " | - 5·2 | 50 " | + 28·5 |
| 12 " | - 7·9 | 80 " | + 3·0 | 55 " | + 18·4 |
| 13 " | - 8·2 | 81 " | + 7·0 | 60 " | + 0·7 |
| 14 " | - 9·0 | 82 " | + 8·2 | 65 " | + 0·8 |
| 15 " | - 9·3 | 83 " | - 0·8 | 70 " | + 9·0 |
| 16 " | - 9·8 | 84 " | - 9·2 | 75 " | + 17·2 |
| 17 " | - 11·4 | 85 " | - 11·0 | 80 " | + 22·0 |
| 18 " | - 13·2 | 86 " | - 2·2 | 85 " | + 33·0 (27)† |
| 19 " | - 15·2 | 87 " | + 13·5 | 90 " | + 34·0 (25) |
| 20 " | - 17·1 | 88 " | + 26·0 | 95 " | + 36·0 (26) |
| 21 " | - 22·5 | 89 " | + 34·2 | 100 " | + 40·0 (15) |
| 22 " | - 31·0 | 90 " | + 34·2 | | |
| 23 " | - 40·1 | 91 " | + 25·8 | | |
| ... " | below | 92 " | + 14·2 | | |
| ... " | - 40 | 93 " | + 0·8 | | |
| 61 " | - 40·0 | 94 " | + 4·5 | | |
| 62 " | - 20·0 | 95 " | + 14·8 | | |
| 63 } 60° | - 11·5 | 96 " | + 20·3 | | |
| 64 } Bé | - 4·8 | 97 " | + 29·2 | | |
| 65 " | - 4·2 | 98 " | + 33·8 | | |
| 66 " | + 1·2 | 99 " | + 36·0 | | |
| 67 } 62° | + 8·0 | 100 " | + 40·0 | | |
| 68 } Bé | + 8·0 | | | | |

* "Fusing Point" is understood to be the temperature to which the mercury of the thermometer, dipping into the solidifying liquid, rises and at which it remains constant. It should be noticed that large quantities of Nordhausen oil of vitriol, such as exist in transportation vessels, frequently do not behave in accord with the above data, because during the carriage and storage a separation often takes place in the acid, crystals of a different concentration being formed, which of course possess a correspondingly different fusing point.

† The figures in parentheses signify the fusing points of *freshly* made Nordhausen oil of vitriol, which has not polymerised.

10. PERCENTAGE OF SO_3 IN OLEUM.

| Per cent. Free SO_3 . | Equivalent per cent. H_2SO_4 . | Per cent. Total SO_3 . | Per cent. Free SO_3 . | Equivalent per cent. H_2SO_4 . | Per cent. Total SO_3 . | Per cent. Free SO_3 . | Equivalent per cent. H_2SO_4 . | Per cent. Total SO_3 . |
|-----------------------------------|--|---------------------------------------|-----------------------------------|--|---------------------------------------|-----------------------------------|--|---------------------------------------|
| 0 | 100.00 | 81.63 | 34 | 107.65 | 87.88 | 68 | 115.30 | 94.12 |
| 1 | 100.23 | 81.82 | 35 | 107.88 | 88.06 | 69 | 115.53 | 94.31 |
| 2 | 100.45 | 82.00 | 36 | 108.10 | 88.25 | 70 | 115.75 | 94.49 |
| 3 | 100.68 | 82.18 | 37 | 108.33 | 88.43 | 71 | 115.98 | 94.67 |
| 4 | 100.90 | 82.37 | 38 | 108.55 | 88.61 | 72 | 116.20 | 94.86 |
| 5 | 101.13 | 82.55 | 39 | 108.78 | 88.80 | 73 | 116.43 | 95.04 |
| 6 | 101.35 | 82.73 | 40 | 109.00 | 88.98 | 74 | 116.65 | 95.22 |
| 7 | 101.58 | 82.92 | 41 | 109.23 | 89.16 | 75 | 116.88 | 95.41 |
| 8 | 101.80 | 83.10 | 42 | 109.45 | 89.35 | 76 | 117.10 | 95.59 |
| 9 | 102.03 | 83.29 | 43 | 109.68 | 89.53 | 77 | 117.33 | 95.78 |
| 10 | 102.25 | 83.47 | 44 | 109.90 | 89.71 | 78 | 117.55 | 95.96 |
| 11 | 102.48 | 83.65 | 45 | 110.13 | 89.90 | 79 | 117.78 | 96.14 |
| 12 | 102.70 | 83.84 | 46 | 110.35 | 90.08 | 80 | 118.00 | 96.33 |
| 13 | 102.93 | 84.02 | 47 | 110.58 | 90.27 | 81 | 118.23 | 96.51 |
| 14 | 103.15 | 84.20 | 48 | 110.80 | 90.45 | 82 | 118.45 | 96.69 |
| 15 | 103.38 | 84.39 | 49 | 111.03 | 90.63 | 83 | 118.68 | 96.88 |
| 16 | 103.60 | 84.57 | 50 | 111.25 | 90.82 | 84 | 118.90 | 97.06 |
| 17 | 103.83 | 84.76 | 51 | 111.48 | 91.00 | 85 | 119.13 | 97.24 |
| 18 | 104.05 | 84.94 | 52 | 111.70 | 91.18 | 86 | 119.35 | 97.43 |
| 19 | 104.28 | 85.12 | 53 | 111.93 | 91.37 | 87 | 119.58 | 97.61 |
| 20 | 104.50 | 85.31 | 54 | 112.15 | 91.55 | 88 | 119.80 | 97.80 |
| 21 | 104.73 | 85.49 | 55 | 112.38 | 91.73 | 89 | 120.03 | 97.98 |
| 22 | 104.95 | 85.67 | 56 | 112.60 | 91.92 | 90 | 120.25 | 98.16 |
| 23 | 105.18 | 85.86 | 57 | 112.83 | 92.10 | 91 | 120.48 | 98.35 |
| 24 | 105.40 | 86.04 | 58 | 113.05 | 92.29 | 92 | 120.70 | 98.53 |
| 25 | 105.63 | 86.22 | 59 | 113.28 | 92.47 | 93 | 120.93 | 98.71 |
| 26 | 105.85 | 86.41 | 60 | 113.50 | 92.65 | 94 | 121.15 | 98.90 |
| 27 | 106.08 | 86.59 | 61 | 113.73 | 92.84 | 95 | 121.38 | 99.08 |
| 28 | 106.30 | 86.78 | 62 | 113.95 | 93.02 | 96 | 121.60 | 99.28 |
| 29 | 106.53 | 86.96 | 63 | 114.18 | 93.20 | 97 | 121.83 | 99.45 |
| 30 | 106.75 | 87.14 | 64 | 114.40 | 93.39 | 98 | 122.05 | 99.63 |
| 31 | 106.98 | 87.33 | 65 | 114.63 | 93.57 | 99 | 122.28 | 99.82 |
| 32 | 107.20 | 87.51 | 66 | 114.85 | 93.76 | 100 | 122.50 | 100.00 |
| 33 | 107.43 | 87.69 | 67 | 115.08 | 93.94 | ... | ... | ... |

11. SPECIFIC GRAVITY OF LIQUID SULPHUR DIOXIDE.

| Temp. | Sp. Gr. | Temp. | Sp. Gr. | Temp. | Sp. Gr. |
|-------|---------|-------|---------|-------|---------|
| -20° | 1·485 | 10° | 1·409 | 35° | 1·344 |
| -10° | 1·460 | 15° | 1·396 | 40° | 1·326 |
| -5° | 1·448 | 20° | 1·383 | 50° | 1·296 |
| 0° | 1·435 | 25° | 1·369 | 60° | 1·263 |
| 5° | 1·422 | 30° | 1·356 | ... | ... |

12. SPECIFIC GRAVITY OF SULPHUROUS ACID SOLUTIONS. (Pellett.)

| Sulphurous acid in 100 c.c. | Specific Gravity. | Sulphurous acid in 100 c.c. | Specific Gravity. |
|--------------------------------|----------------------|--------------------------------|----------------------|
| 1 | 1·0075 | 4 | 1·0300 |
| 2 | 1·0150 | 5 | 1·0375 |
| 3 | 1·0225 | 6 | 1·0450 |

13. The Quantitative Examination of Sulphurous Acid and Sulphites.

The quantitative estimation of free sulphurous acid is made by titration with standard hydroxide, using either phenolphthalein or methyl orange as indicator, but not litmus. With phenolphthalein, the colour change to red is reached when the normal salt Na_2SO_3 is formed, so that 1 c.c. of normal alkali corresponds to 0·03203 g. SO_2 , but with methyl orange, the change to yellow is reached at the formation of NaHSO_3 , so that 1 c.c. of normal alkali corresponds to 0·06406 g. SO_2 .

The reducing property of sulphuric acid serves also as a basis for its estimation. The method consists in running the acid into a decinormal iodine solution, 1 c.c. of which indicates 0·003203 g. SO_2 .

A combination of the two methods of estimation enables the percentage of normal sulphite, acid sulphite, and free sulphurous acid present in a solution to be estimated.

14. The Quantitative Examination of Free Sulphuric Acid.

The quantitative examination of free sulphuric acid is made by titrating a weighed quantity. It is not sufficiently accurate to measure the acid by a pipette, etc., especially in the case of concentrated acid. The titration is performed by means of standard sodium hydroxide solution, and the results are expressed in terms of H_2SO_4 .

Weigh from 2 to 3 g. acid in a glass-tap pipette (Fig. 14, p. 172), after cleaning the latter on the outside; run its contents into at least 100 c.c. water, and weigh the pipette again, *without* washing it out. This enables another pipette full of acid to be taken and tested, without washing and drying the instrument, and so forth. The same procedure is also very well adapted for slightly fuming mixtures of sulphuric and nitric acid, and for Nordhausen oil of vitriol (*cf.* p. 171).

The standard sodium hydroxide solution is "normal," *i.e.* containing 0.04001 g. NaOH per c.c. It is controlled by means of standard hydrochloric acid (0.03647 g. HCl per c.c.), the strength of which has been fixed by pure sodium carbonate.

As indicator, methyl orange is used always in the cold, and so much only is taken that the colour produced is just visible. Nitrous acid destroys this colouring matter, but ordinary commercial acid never contains sufficient to cause any trouble, and even "nitrous vitriol" or fuming nitric acid can be treated with methyl orange, if the indicator is added (or renewed) shortly before the last quantity of alkali has been added; or else an excess of alkali is added, then methyl orange, and titrated back. Nitrous acid behaves towards methyl orange like the strong mineral acids; that is, the change of colour takes place when the compound $NaNO_2$ has been formed.

15. Examination of Sulphuric Acid for other Substances.

(a) *Nitrous Acid* (Nitrososulphuric Acid) is titrated with seminormal permanganate. This can be done without loss of NO by manipulating as follows (Lunge, *Berliner Berichte*, x., 1075):—Put the nitrous vitriol into a burette fitted with a glass tap, run it slowly into a measured quantity of permanganate, diluted with five times its volume of tepid water (30° C. to 40° C.), and agitate continuously till the colour just vanishes. Sometimes during this process a little manganese dioxide is separated, which makes it difficult to recognise the end of the reaction; but this is avoided by keeping the temperature not above 40° and by diluting the permanganate, say to 200 c.c. (The same method

holds good for the analysis of *sodium nitrite*, but in this case the permanganate solution must be previously acidulated to such an extent that the NaNO_2 solution is immediately decomposed

TABLE FOR ESTIMATING NITROUS VITRIOL.

Employ 50 c.c. of seminormal permanganate. The results are expressed as HNO_3 and NaNO_3 . The column *y* refers to acid of 140°Tw . as unit :—

| Acid consumed. <i>y</i> . c.c. | HNO_3 . | | NaNO_2 . | | Acid consumed. <i>y</i> . c.c. | HNO_3 . | | NaNO_3 . | |
|--------------------------------------|--------------------------------|----------------------------|--------------------------------|----------------------------|--------------------------------------|--------------------------------|----------------------------|--------------------------------|----------------------------|
| | <i>a</i> . g. per litre. | <i>b</i> . per cent. | <i>a</i> . g. per litre. | <i>b</i> . per cent. | | <i>a</i> . g. per litre. | <i>b</i> . per cent. | <i>a</i> . g. per litre. | <i>b</i> . per cent. |
| 10 | 78.75 | 4.61 | 106.29 | 6.22 | 36 | 21.88 | 1.28 | 29.53 | 1.73 |
| 11 | 71.59 | 4.19 | 96.63 | 5.65 | 37 | 21.28 | 1.24 | 28.72 | 1.68 |
| 12 | 65.63 | 3.84 | 88.58 | 5.18 | 38 | 20.72 | 1.21 | 27.97 | 1.64 |
| 13 | 60.58 | 3.54 | 81.76 | 4.78 | 39 | 20.19 | 1.18 | 27.25 | 1.59 |
| 14 | 56.25 | 3.29 | 75.92 | 4.41 | 40 | 19.69 | 1.15 | 26.53 | 1.55 |
| 15 | 52.50 | 3.07 | 70.86 | 4.14 | 41 | 19.21 | 1.12 | 25.83 | 1.51 |
| 16 | 49.22 | 2.88 | 66.43 | 3.88 | 42 | 18.75 | 1.10 | 25.31 | 1.48 |
| 17 | 46.32 | 2.71 | 62.52 | 3.65 | 43 | 18.27 | 1.07 | 24.66 | 1.44 |
| 18 | 43.75 | 2.56 | 59.05 | 3.45 | 44 | 17.90 | 1.05 | 24.16 | 1.41 |
| 19 | 41.45 | 2.42 | 55.95 | 3.27 | 45 | 17.76 | 1.02 | 23.57 | 1.38 |
| 20 | 39.38 | 2.30 | 53.15 | 3.11 | 46 | 17.12 | 1.00 | 23.11 | 1.35 |
| 21 | 37.50 | 2.19 | 50.61 | 2.96 | 47 | 16.72 | 0.978 | 22.57 | 1.32 |
| 22 | 35.80 | 2.09 | 48.32 | 2.83 | 48 | 16.41 | 0.960 | 22.15 | 1.30 |
| 23 | 34.24 | 2.00 | 46.21 | 2.70 | 49 | 16.01 | 0.938 | 21.65 | 1.27 |
| 24 | 32.81 | 1.92 | 44.28 | 2.59 | 50 | 15.75 | 0.921 | 21.26 | 1.24 |
| 25 | 31.50 | 1.84 | 42.52 | 2.49 | 55 | 14.32 | 0.837 | 19.33 | 1.13 |
| 26 | 30.29 | 1.77 | 40.88 | 2.39 | 60 | 13.13 | 0.768 | 17.72 | 1.04 |
| 27 | 29.17 | 1.71 | 39.37 | 2.30 | 65 | 12.12 | 0.709 | 16.36 | 0.957 |
| 28 | 28.13 | 1.65 | 37.97 | 2.22 | 70 | 11.25 | 0.658 | 15.18 | 0.888 |
| 29 | 27.16 | 1.59 | 36.66 | 2.14 | 75 | 10.50 | 0.614 | 14.17 | 0.829 |
| 30 | 26.25 | 1.54 | 35.43 | 2.07 | 80 | 9.85 | 0.576 | 13.29 | 0.777 |
| 31 | 25.40 | 1.49 | 34.28 | 2.00 | 85 | 9.26 | 0.542 | 12.50 | 0.731 |
| 32 | 24.61 | 1.44 | 33.22 | 1.94 | 90 | 8.73 | 0.511 | 11.78 | 0.689 |
| 33 | 23.86 | 1.40 | 32.20 | 1.88 | 95 | 8.29 | 0.485 | 11.19 | 0.654 |
| 34 | 23.16 | 1.35 | 31.26 | 1.83 | 100 | 7.88 | 0.461 | 10.64 | 0.622 |
| 35 | 22.50 | 1.32 | 30.37 | 1.78 | | | | | |

N.B.—The figures in column *a* also indicate 0.01 lb. avoirdupois per gallon, or nearly ounces per cubic foot.

when run into the permanganate.) Each cubic centimetre of the permanganate indicates 0.009502 g. N_2O_3 , hence more or less of it is employed, according as to whether an acid containing more or less N_2O_3 is titrated. For chamber acid, employ at

most 5 c.c.; for good Gay-Lussac acid, up to 50 c.c. of permanganate. If the quantity of permanganate is called x , and that of the vitriol consumed for decolorising it y , the quantity of N_2O_3 present in grams per litre of acid is:—

$$\begin{array}{rcl} & \frac{9.502x}{y} & \\ \text{Calculated as} & \text{HNO}_3 = \frac{15.75x}{y} & \\ \text{as} & \text{NaNO}_3 = \frac{21.253x}{y} & \end{array}$$

The preceding table, p. 163, saves the calculation for all cases in which $x=50$. The column y gives the number of cubic centimetres of nitrous vitriol used, a the percentage in grams per litre, and b the percentage by weight, for acid of 140° Tw. (For other strengths the percentage by weight is calculated by dividing the figures of column a by $10 \times$ specific gravity.)

(b) *Total Nitrogen Acids*.—These are contained in sulphuric acid as N_2O_3 , or more correctly as nitrososulphuric acid, $\text{SO}_2(\text{OH})(\text{ONO})$, and HNO_3 . NO can be present only in minute quantity, and only in absence of HNO_3 . N_2O_4 is decomposed by sulphuric acid into nitrososulphuric and nitric acid. The estimation made according to (a) only indicates N_2O_3 . The total nitrogen acids are converted into NO by shaking up the nitrous vitriol with mercury; the quantity of NO formed is estimated by volume (Crum's reaction). This is done by Lunge's *Nitrometer*, Fig. 41, p. 165. Fill the graduated limb a with mercury by raising the level tube b ; put the three-way tap so that it communicates with any of the openings; run the nitrous vitriol into the top cup of a from a 1 c.c. pipette graduated in $\frac{1}{100}$ c.c., employing only 0.5 c.c. of very strong, but up to 5 c.c. of very weak nitrous vitriol; lower the level tube, open the tap carefully so that the vitriol runs in without any air entering; pour 2 or 3 c.c. of pure strong sulphuric acid, free from nitrogen compounds, into the cup; let this acid enter the nitrometer, and repeat the washing of the cup with 1 or 2 c.c. of pure acid. Start the evolution of gas by taking the tube a out of the clamp, inclining it several times till almost horizontal, and suddenly righting it again, so that mercury and acid are well mixed; shake for one or two minutes till no more gas is evolved. Place the tubes so that the mercury in b is as much higher than that in a as is required for balancing the acid in a ; this requires 1 mm. of Hg for $6\frac{1}{2}$ mm. of acid. An exact reading can only be obtained when the gas has attained the temperature of the room and all froth has subsided. Read off the volume of the gas, also a thermometer hung up close by, and the barometer. In order to check the levelling, open the

tap, when the level of *a* should not change. If it rises, the pressure has been in excess, and the reading must be increased a little, say by 0.1 c.c. If it sinks, the reverse is the case, *i.e.* always in the opposite sense to the change of level. Another plan is, to put a little acid into the cup before opening the tap. This will be sucked in if the pressure was too low, or raised if too high. With adroit manipulation the reading can then soon be corrected. Finally, lower the graduated tube *a*, lest any air should enter on opening the tap; open the tap, raise the tube *b*,

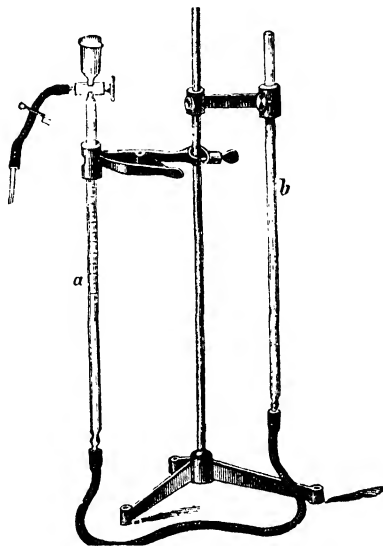


FIG. 11.

force the gas and all acid into the cup, and turn the tap so that the acid flows through into a vessel held below; the last portions are drawn off by blotting-paper. The nitrometer is then ready for the next experiment.

A test must always be made to see whether the glass tap is gas-tight. It will hardly remain so without greasing it occasionally with vaseline, but this ought to be done very slightly, so as to avoid any grease getting into the bore, for if the grease comes in contact with acid, troublesome froth is formed.*

* Such froth may also be formed in the presence of too much water, by the separation of mercuric sulphate, but this hardly ever happens in the case of nitrous vitriol, and even in the analysis of sodium nitrate only when the description given for the estimation is not properly adhered to.

This process is interfered with by the presence of sulphurous acid, the best test for which is the smell. To remove it, the acid is stirred up with a very small quantity of powdered potassium permanganate. Any great excess of this acid makes the process very troublesome and inaccurate.

In highly concentrated acids a notable quantity (up to 3 per cent. by volume) of NO may be dissolved; therefore a little water must be added to such acids in the nitrometer, sufficient to reduce their strength to about 90 per cent. H_2SO_4 . The volume of NO read off is reduced to 0° C. and 760 mm. (32° F. and 29.92 in.) by means of the tables, pages 20 *et seq.*, and calculated for the nitrogen compounds present by the table on this page, in which column *a* gives milligrams, *b* per cent. by weight, when employing 1 c.c. acid of 140° Tw.

| c.c. NO read off. | a. Absolute weight, mg. | b. Per cent. by weight, when em- ploying 1 c.c. acid of 140° Tw. in the Nitrometer. |
|---|-------------------------------|--|
| Nitrogen, N_2 | 0.6256 | 0.0366 |
| Nitric oxide, NO | 1.3403 | 0.0784 |
| Nitrogen trioxide, N_2O_3 | 1.6974 | 0.0993 |
| Nitric acid, real, HNO_3 | 2.8143 | 0.1646 |
| Sodium nitrate, NaNO_3 | 3.7963 | 0.2221 |
| Potassium nitrate, KNO_3 | 4.5176 | 0.2642 |

(Multiples of these figures are given in Table 27, p. 73.)

Nitrometers (and gas-volumeters) should of course be obtained from a reliable dealer, so that the correctness of the graduations and the tightness of the taps can be depended upon.

The reduction to 0° and 760 mm. can be effected without thermometer and barometer, and without the use of any tables, by means of Lunge's *Gas-volumeter*, Fig. 12, which serves also for numerous other analytical operations. It consists of the gas-measuring tube A, the reduction tube B, and the level tube C, all connected by thick rubber tubing with the three-way tube *a*. B and C are held in two arms of the same clamp, so as to be each either individually movable in its own arm, or both together by means of the common clamp. Tube A may be an ordinary nitrometer with three-way tap and funnel; it is, however, best employed merely as a gas-measuring tube, and for some purposes this tube is made to hold upwards of 100 c.c., in which case the upper portion is in the shape of a bulb, the division beginning below this, say, at 90 or 100 c.c. The most convenient shape,

which serves both for small and large quantities of gas, is a tube possessing a bulb in the middle, and graduated above this from 0 (at the tap) to 40 c.c., below the bulb from 100 to 140 c.c. A two-way tap, *g*, allows communication either with the straight outlet tube *h*, or with the right-angle tube *e*.

Instead of carrying out the decomposition in tube A, it is decidedly preferable to employ for this purpose a separate tube D, provided with a two-way tap *f*, a funnel *d*, and an outlet tube *c*, corresponding to the tube *e* on A. D has its own

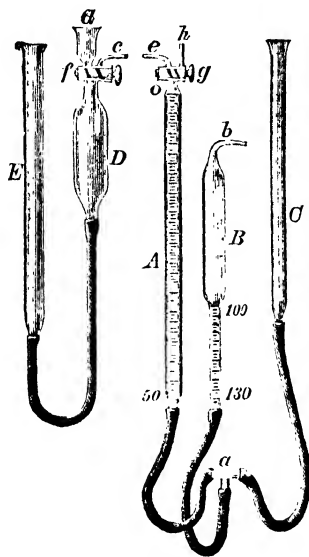


FIG. 12.

level tube E. All these tubes are held in clamps, which can be moved up and down on the two bars of a heavy iron stand.

The "reduction tube" B is enlarged at the top, and the narrow portion below is graduated from 100 to 125 c.c. in $\frac{1}{10}$ c.c. It contains a volume of dry air which at 0° and 760 mm. pressure would occupy exactly 100 c.c. This is obtained by taking, once for all, a reading of the thermometer and the barometer, and calculating what would be the volume of 100 c.c. of dry air under the prevailing atmospheric conditions. In reading the barometer, a deduction must be made for the expansion of the mercury, viz., 1 mm. between 0°

and 12° , 2 mm. between 13° and 19° , 3 mm. between 20° and 25° . For calculating the volume of 100 c.c. air at "normal conditions" from the observed temperature t and the barometric reading b (corrected as above), we have the formula:—

$$V = \frac{100(273 + t)760}{273b}$$

A drop of concentrated sulphuric acid is previously introduced through the open end of b , most conveniently by suction. After setting the level in B to the point indicated by the equation, the capillary end of b is sealed by fusing it up; in order to prevent the heat from expanding the air in B, a cardboard shield is put between the flame and B.

This is avoided by replacing the open capillary tube b by Lunge's "beaker-tap" (*Ber.*, 1892, p. 3157), and still better by Göckel's gas-tap with annular mercury seal.

The "laboratory vessel" or "decomposition tube" D, in which the reaction is carried out, is provided with the fittings of an ordinary nitrometer, viz., the three-way tap f , the cup d , the lateral outlet c , and the special level tube E. It holds about 150 c.c. and is not graduated. Mercury is poured in through E. By raising E, the vessel D is completely filled with mercury, till it begins to run out at c . The tap f is shut, the end of c closed by a glass or rubber cap, and the nitrous vitriol placed in d ; this is sucked into D, then some pure acid sucked in, to wash the cup and tap, tap f closed (no bubbles of air must remain below it!), and the decomposition brought about in the usual manner by shaking the vitriol with the mercury, to evolve all the nitrogen acids as NO. The tubes D and A are then brought opposite to each other (A having been previously filled, by raising C, with mercury till it flows out at e); c and e are joined by a short piece of rubber tubing till they touch, so that no air remains in the space between; C is lowered, E raised, and by cautiously opening tap f , the NO contained in D is transferred into A. As soon as all the gas is in A, and the acid following it has filled the narrow tube e , tap g is closed. Now tube C is raised till the mercury in B has risen to the mark 100, and B and C are simultaneously moved up or down, as may be required, till the levels in A and B coincide, that in B being still at 100 c.c. Since the air in B is now compressed to the point which it would occupy in the dry state at 0° and 760 mm., and the gas in A is placed under exactly the same pressure (the temperature of these two parallel tubes being presumably the same), the reading in A gives the volume of NO reduced to the same conditions of 0° and 760 mm. The temperature in A and B must be exactly the same; this is ensured by the conductivity of the mercury, but in the case of large quantities of NO it is necessary to wait at least ten minutes before finally adjusting the levels.

If only one gas-volumeter is available, and that is adjusted for *moist* gases (as is required for other purposes), it may be used also for dry gases, but it is then necessary to avoid any sulphuric acid passing from D into A, and to suck a drop of water into A, before transferring the gas into it from D. Another way for measuring *dry* gases with a *moist* reduction tube is as follows:—observe the temperature; take the tension of aqueous vapour corresponding to this from the table, p. 36= f , and adjust the mercury in the measuring tube A higher by f mm. than in the reduction tube B, where as usual, the mercury is adjusted by means of the level tube C to the point marking 100·00 c.c. If, on the other hand, a reduction tube has been prepared for *dry* gases, by introducing a drop of concentrated acid, it may be used for *moist* gases (as in the testing of manganese ore, bleaching powder, potassium permanganate, etc.), by adjusting the mercury in A f mm. lower than in B.

(c) *Relative Proportions of the three Nitrogen Acids*.—In order to find from the result of the permanganate titration and from the estimation of total nitrogen in the nitrometer (as NO) the relative proportions of N_2O_3 , N_2O_5 , and HNO_3 in a mixture of all three nitrogen acids absorbed by sulphuric acid, we may employ the following formula:—

a = c.c. NO found in the nitrometer.

b = c.c. O, calculated from the permanganate titration.

(1 c.c. O = 1·4292 mg.; 1 c.c. seminormal permanganate = 0·004 g. = 2·7975 c.c. oxygen.)

x = vols. NO, corresponding to the N_2O_3 present.

y = „ NO, „ „ „ N_2O_5 „ „

z = „ NO, „ „ „ HNO_3 „ „

If $4b$ be $> a$,

$$x = 4b - a; y = 2(a - 2b), \text{ or } -a - x.$$

If $4b$ be $< a$,

$$y = 4b; z = a - 4b.$$

(d) *Qualitative Test for Traces of Nitrogen Acids*.—These can be detected by means of diphenylamine. Dissolve a few grams of diphenylamine in 100 parts of pure sulphuric acid. This acid should be completely free from nitrogen oxides, and can be made so, if not at hand, by boiling with a trace of ammonium sulphate. Dilute the acid with $\frac{1}{10}$ th volume of water before dissolving the diphenylamine. This solution may be employed at once, or kept, as it keeps quite well. Pour about 2 c.c. of the vitriol to be tested into a test-tube, and add about 1 c.c. of the diphenylamine solution so that the layers mix only gradually. In the case of dilute acids, or other lighter liquids, proceed in the opposite manner. The slightest traces of nitrogen acids are detected by the appearance of a brilliant blue colour at the area of contact of the liquids.

The smallest traces of nitrous acid are detected, even in the presence of nitric acid, by the reagent proposed by Griess, as modified by Ilosvay and by Lunge. This reagent is prepared by (1) dissolving 0.5 g. sulphanilic acid in 150 c.c. dilute acetic acid; (2) boiling 0.1 g. solid α -naphthylamine with 20 c.c. water, pouring the colourless liquid off from the purple residue, and mixing it with 150 c.c. dilute acetic acid. The two solutions are united, and can thus be kept for an indefinite time in a bottle, well protected against air (which often contains traces of nitrogen acids). Add a few c.c. of this solution to the solution to be tested, and heat to 70° or 80°. If as little as 1 part nitrous acid be present in 1000 million parts of the liquid, a red colour is formed in about one minute. More concentrated solutions of HNO_3 , say 1 : 1000, do not yield the blue colour, but a yellow solution.

In the presence of selenium the diphenylamine test fails, as Se gives the same reaction as nitrogen acids. In that case test for somewhat large quantities of nitrogen acids by the decoloration of indigo solution; for traces, by the reddening of a solution of brucine sulphate.

(c) *Selenium* in sulphuric acid can be recognised by adding to the acid a strong solution of ferrous sulphate, when a brownish-red precipitate will make its appearance, which cannot be confused with the colour produced by NO. It can also be recognised by the green colour, produced in a solution of codein.

(f) *Examination for Lead*.—Dilute the acid, if concentrated, with an equal volume of water and twice its volume of alcohol. Allow the mixture to stand for some time, filter any precipitate of PbSO_4 , wash it with dilute alcohol, and dry and ignite in a porcelain crucible, burning the filter separately. 1 g. $\text{PbSO}_4 = 0.6829$ g. Pb.

(g) *Examination for Iron*.—Boil the acid, if free from nitrogen, with a drop of nitric acid to oxidise the iron. Dilute a little, allow to cool, and add a solution of potassium thiocyanate. A red colour proves the presence of iron. If there is not too little, it can be quantitatively estimated in another sample by heating with pure zinc (free from iron), pouring off from the zinc, washing the latter, allowing to cool, and titrating with permanganate. This is best employed as $\frac{1}{20}$ th normal, indicating 0.002792 g. Fe per cubic centimetre. Not less than 50 c.c. of the acid should be taken for this test, as it generally contains very little iron.

The smallest traces of iron can be estimated colorimetrically (Lunge, *Zsch. f. angew. Chem.*, 1896, p. 3).

(h) *Arsenic* is detected qualitatively by the well-known methods of Marsh or of Reinsch. For quantitative estimation dilute 20 c.c. of the acid with water, and treat with a current of SO_2 , until there is a strong smell of the gas. This reduces As_2O_5 to As_2O_3 , but it requires a long time and a considerable excess of

SO_3 . Now drive off this excess by heating and passing in a current of CO_2 , neutralise exactly with Na_2CO_3 and a little NaHCO_3 , add starch and titrate with decinormal iodine. 1 c.c. of the iodine solution indicates 0.00495 g. As_2O_3 . (Any considerable proportion of iron should be previously removed.)

(i) *Chlorides*.—Boil 10 c.c. of the acid in a flask, pass the vapours on to the surface of a little water, contained in a flask, and estimate the absorbed HCl acidimetrically, or after neutralising with Na_2CO_3 , by titrating with decinormal silver nitrate (p. 174).

16. Analysis of Fuming Sulphuric Acid (Oleum) and of Sulphuric Anhydride.

Although other tests are often carried out (among which that for arsenic is the most usual) the estimation most frequently made is that of the total acidity.

The substance is either weighed in glass bulbs or in a glass-tap tube. The former are very thin bulbs of about 2 cm. diameter, ending on each side in a capillary tube. Melt the acid, if solid, till it is completely homogeneous, and suck 3 g. to 5 g. into the bulb, which ought to be half-filled with it. The sucking is best done by means of a bottle closed with a rubber cork, through which passes a tightly fitting glass tap, connected at its free end with a rubber tube. Suction is applied to the latter, the tap closed, the rubber tube drawn over one of the capillary ends of the weighing bulb, and by opening the tap a sufficient quantity of acid admitted into the bulb. The tube is cleaned outside, and one of the capillary ends is sealed off. The other end can be left open without fear of any loss of SO_3 or attraction of moisture during weighing. The weighing is best done on a small platinum crucible with two nicks, on which the ends of the bulb can rest. If the latter should be accidentally broken, the acid runs into the crucible, not on to the balance. Put the bulb, after weighing, open end downwards into a small Erlenmeyer flask, into the neck of which it ought to fit exactly (Fig. 13), and which contains so much water that the capillary tube dips well into it, to prevent any loss of SO_3 on mixing the acid with water. Break off the other point, allow the acid to run out, squirt a few drops of water into the upper capillary, and ultimately rinse the whole bulb tube by repeated aspiration of water. Dilute the liquid to 500 c.c. and take 50 c.c. for each test. This is done with $\frac{1}{5}$ normal sodium carbonate solution (1 c.c. = 0.008007 g. SO_3), and methyl

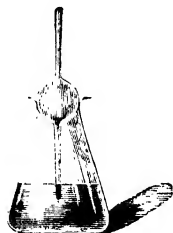


FIG. 13.

orange as indicator. From the acidity found, that due to SO_2 is deducted, which is ascertained by titrating another sample with iodine.

Lunge and Rey's glass-tap pipette (Fig. 14) (the taps of which must be tight without greasing!) is more convenient than the bulb tube. Shut the lower tap *c*, open the upper tap *a*, apply suction (with the mouth) at *d*, and shut *a* whilst sucking. Immerse the point *e* in the acid to be tested, and open *c*; the partial vacuum in bulb *b* suffices for drawing up enough acid, which must not be allowed to reach the tap *c*. Shut *c*, clean the point *e*, put the pipette in the outer glass vessel *f*, and weigh. Take the pipette out of *f*, place it point downwards in water, and slowly run out the contents. Then squirt some water from above into *b*, allow to stand for a moment, and rinse thoroughly with water.



FIG. 14.

The strongest fuming oil of vitriol cannot be run directly into water without loss. Such oil of vitriol is weighed out in small glass bulbs, as described above; both ends are sealed up, the bulb is placed in a bottle containing a considerable quantity of water, the stopper put in, the bulb broken by shaking the bottle, and after waiting a little the solution titrated.

Solid products of this class must be melted by moderate heating; they then remain long enough in the liquid state to complete the weighing and running out without being heated again. But products which are not far removed from real SO_3 in composition would give out too much vapour in this operation. Such products are weighed out in a stoppered bottle, and mixed in this with a known and exactly analysed quantity of monohydrate, at a temperature of 30° to 40° C. This ought to produce a mixture containing about 70 per cent. SO_3 which will remain liquid at ordinary temperatures.

If only 0.5 to 1 g. of acid has been weighed off, titrate directly. This is more accurate than diluting and titrating only part of the liquid, but the latter method cannot be avoided when a larger quantity of acid has been weighed.

The acidimetric determination, of course, indicates the total percentage of acid. From this we must deduct in the first instance any SO_2 present. This is estimated in the usual way by decinormal iodine, and for each c.c. of this 0.05 c.c. normal sodium carbonate solution is deducted (since with methyl orange the

colour changes when SO_2 has passed into NaHSO_3). If we call the c.c. of normal sodium carbonate used $=n$, those of decinormal iodine used for the same quantity of oil of vitriol $=m$, the acidity due to $\text{H}_2\text{SO}_4 + \text{SO}_3$ is $=(n - 0.05 m) 0.040035 \text{ SO}_3$. To the SO_3 thus found add the SO_2 (calculated $=0.0032035 m$), and assume the residue to be water.* By multiplying this H_2O by 4.445, we obtain the quantity of SO_3 combined with it to form H_2SO_4 , and by deducting this from the total SO_3 acidity, that of the free SO_3 .

PLANT TEST FOR FREE TRIOXIDE IN OLEUM.

Curtis and Miles have described a simple test which can be applied by a workman on the plant. The apparatus required is of the simplest kind—an earthenware jug or mug holding about a pint, two glass cylinders each holding 200 c.c., and a thermometer, which is preferably protected by sealing into a light iron case perforated with holes at the lower end.

To carry out the test, measure 200 c.c. of sulphuric acid (92.5 to 94.5 per cent.) into the mug and have ready 200 c.c. of oleum in the cylinder. Take the temperature of each, and then quickly pour the oleum into the acid, stirring vigorously all the time. Note the maximum temperature of the mixture, and calculate the increase, I , as follows:—

$$I = t_{\text{mixture}} - \frac{t_{\text{acid}} + t_{\text{oleum}}}{2}$$

Reference to the table below gives the percentage of free anhydride:—

| Increase of Temp. I . | Per cent. SO_3 . | Increase of Temp. I . | Per cent. SO_3 . | Increase of Temp. I . | Per cent. SO_3 . | Increase of Temp. I . | Per cent. SO_3 . |
|-------------------------|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|
| 1 | ... | 11 | 5.9 | 21 | 12.1 | 31 | 18.7 |
| 2 | 0.0 | 12 | 6.5 | 22 | 12.8 | 32 | 19.4 |
| 3 | 0.6 | 13 | 7.2 | 23 | 13.4 | 33 | 20.1 |
| 4 | 1.3 | 14 | 7.8 | 24 | 14.1 | 34 | 20.8 |
| 5 | 2.0 | 15 | 8.5 | 25 | 14.7 | 35 | 21.4 |
| 6 | 2.6 | 16 | 9.7 | 26 | 15.4 | 36 | 22.0 |
| 7 | 3.2 | 17 | 9.1 | 27 | 16.0 | 37 | 22.7 |
| 8 | 3.9 | 18 | 10.3 | 28 | 16.7 | 38 | 23.4 |
| 9 | 4.6 | 19 | 10.9 | 29 | 17.4 | 39 | 24.1 |
| 10 | 5.3 | 20 | 11.5 | 30 | 18.0 | 40 | 24.7 |

The results from this table are correct to within ± 0.5 per cent. The strength of the sulphuric acid may vary from 92.5 to 94.5 per cent. but should not go outside these limits.

* In case any weighable quantity of solid impurities is present, this must also, of course, be deducted.

V. SALTCAKE AND HYDROCHLORIC ACID.

A.—Salt (Common Salt, Rock-Salt.)

1. *Moisture*.—Ignite 5 g. of salt in a covered platinum crucible (to prevent loss by spirting); heat first quite gradually, then for some minutes, up to a low red heat. If the sample is too damp, or if several samples are to be tested at the same time, weigh off the 5 g. samples in flat-bottomed Erlenmeyer flasks, with funnels on, heat a number of these on a sand-bath for three or four hours to 140° or 150° (without funnel), and allow them to cool with the funnel in, which saves the use of a desiccator. Afterwards the small remainder of chemically combined water may be removed by heating on a wire-gauze, but this is mostly unnecessary.

2. *Insoluble matter*.—Dissolve 5 g., filter the insoluble matter, wash, dry, and ignite.

3. *Chlorine*.—Weigh off 5.846 g. of the moist salt, dissolve it, and dilute to 500 c.c.; take out 25 c.c. by means of a pipette, add so much of a solution of neutral potassium chromate that the liquid is distinctly yellow, and titrate with decinormal silver solution. Add the silver solution from a 50 c.c. burette, till the precipitate, even after agitation, shows a distinct but faint pink colour. 0.2 c.c. is deducted from the number of cubic centimetres of silver solution used, as being required for producing the colour. The remainder, multiplied by 2, gives the percentage of NaCl in the salt. In lieu of potassium chromate, sodium arsenate may be employed as indicator. This is even more sensitive, and no deduction from the silver solution used should be made in this case.

4. *Lime*.—Dissolve 5 g. of the salt in water, if necessary with the aid of a little HCl. When analysing impure rock-salt, the treatment with dilute HCl must be continued for some time, in order to dissolve all CaSO_4 . It is also necessary to filter off any clay, etc., but non-argillaceous salt ought to dissolve completely, excepting any grains of sand and the like. In the clear solution precipitate the lime with ammonia and ammonium oxalate, allow to stand for twelve hours, filter the precipitate through a fine filter-paper in a well-shaped funnel (cf. p. 134), wash, dry, and ignite it in a platinum crucible till it is completely converted into CaO. This is done by first gently heating till the calcium oxalate is decomposed, and then igniting at nearly a white heat for twenty minutes, either over a gas blowpipe or, more conveniently, in a Hempel's gas-oven or over a Muencke burner. One part CaO is equal to 2.4281 CaSO_4 , and is calculated as such.

5. *Sulphates*.—Dissolve 10 g. of the salt in tepid water, with addition of a little hydrochloric acid. Dilute to 1 litre, filter through a dry pleated filter, and precipitate 250 c.c. (=2.5 g. salt) by barium chloride (cf. p. 134). The sulphate is usually calculated as CaSO_4 .

6. *Magnesium Chloride* may be titrated directly by drying the salt, extracting it with absolute alcohol, filtering, evaporating off the alcohol from the filtrate (which contains nothing but MgCl_2), and titrating with silver nitrate.

B.—Saltcake (Sulphate of Soda).

(*N.B.*—Nos. 1 and 2 are sufficient for the daily checking of the manufacture; the others are employed for saltcake when bought and sold.)

1. *Free Acid*.—Dissolve 20 g. saltcake, dilute to 250 c.c., take out 50 c.c. with a pipette, add methyl orange, and titrate with standard sodium carbonate to the point of neutralisation. Each cubic centimetre of the standard alkali is equal to 1 per cent. SO_3 . The total acidity is calculated as SO_3 , including HCl and NaHSO_4 . (If litmus were employed as indicator, the presence of salts of iron and alumina would cause trouble in the titration; with methyl orange this is not the case.)

2. *Sodium Chloride*.—Take another 50 c.c. of the solution made for the test No. 1, add the same quantity of standard alkali as used for this test, so that the acid is exactly neutralised, then a little neutral potassium chromate, and titrate with decinormal silver solution, as in A, 3. Each cubic centimetre of silver solution (after deducting 0.2 from the whole) is equal to 0.1462 per cent. NaCl . Or else employ a solution containing 2.906 g. AgNO_3 per litre and indicating 0.001 g. NaCl per cubic centimetre. This would, in the present case, indicate 0.025 per cent. NaCl per cubic centimetre.

3. *Iron*.—Dissolve 10 g. of sulphate in water, reduce the iron salts to the ferrous state by a little sulphuric acid and zinc, and titrate with potassium permanganate.

4. Residue, insoluble in water, is estimated as usual, if present.

5. *Lime*.—Dissolve 10 g. in water, if necessary with a little HCl ; add NH_4Cl and NH_3 , precipitate with ammonium oxalate, ignite, and weigh as CaO . If any appreciable quantity of Fe_2O_3 has been found, this must be deducted.

6. *Magnesia* is precipitated in the filtrate from No. 5 by ammonium phosphate; allow to stand for twenty-four hours; filter, wash with dilute ammonia, dry, ignite, and weigh the magnesium pyrophosphate, of which 1 part = 0.3621 MgO .

7. *Alumina*.—The solution of the saltcake is precipitated by ammonia (free from CO_2). The precipitate is ignited and weighed.

Deducting the weight of Fe_2O_3 found in No. 3, the remainder is $=\text{Al}_2\text{O}_3$.

8. *Sodium Sulphate (direct estimation).*—Dissolve 1 g. of the saltcake; precipitate any lime together with ferric oxide, etc., as in No. 5; filter; evaporate the filtrate to dryness after adding a few drops of pure sulphuric acid; ignite; repeat this after adding a small piece of ammonium carbonate, and weigh. Deduct from this weight (1) the NaCl found in test No. 2, calculated for Na_2SO_4 ($1\cdot0000 \text{ NaCl} = 1\cdot2151 \text{ Na}_2\text{SO}_4$), or each cubic centimetre of decinormal silver solution employed in test No. 2 $= 0\cdot001776 \text{ g. Na}_2\text{SO}_4$); (2) the MgO found in test No. 6 calculated as MgSO_4 ($1\cdot000 \text{ MgO} = 2\cdot9859 \text{ MgSO}_4$). The remainder is equal to the sodium sulphate actually present in 1 g. saltcake.

C.—Chimney-Testing.

Act of Parliament.—By the Alkali Works Regulation Act of 1906, it is enacted that "Every alkali work shall be carried on in such a manner as to secure the condensation to the satisfaction of the chief inspector, (a) of the muriatic acid gas evolved in such work to the extent of 95 per centum, and to such an extent that in each cubic foot of air, smoke, or chimney gases escaping from the works into the atmosphere, there is not contained more than *one-fifth part of the grain* [$= 0\cdot457 \text{ g. per cubic metre}$] of muriatic acid; (b) of the acid gases of sulphur and nitrogen which are evolved in the process of the manufacture of sulphuric acid in that work to such an extent that the total acidity of such gases in each cubic foot of residual gases after completion of the process, and *before* admixture with air, smoke, or other gases, does not exceed what is equivalent to *four grains* of sulphuric anhydride; (c) in the residual gases from the concentration or distillation of sulphuric acid, the total acidity of gases in each cubic foot must not exceed the equivalent of $1\frac{1}{2}$ grain of sulphuric anhydride."

Hydrochloric Acid in Chimney Gases.—In order to ascertain the HCl in chimney gases, an aspirator is used known as Fletcher's flexible aspirator, or bellows. This aspirator is supposed to draw at one aspiration one-tenth of a cubic foot. It is not safe to trust to this supposed capacity, and moreover the capacity of a new aspirator varies for some time. To ascertain the real capacity, fill a very large beaker or other cylindrical vessel with water, and invert it under water. Completely fill the aspirator with air, and expel this air into the inverted beaker. Mark the point to which the beaker is filled when the water inside the beaker is level with that outside. Measure the capacity of the beaker to that mark; say it contains V cubic centimetres of water.

Then the number of aspirations which must be made with this aspirator in order to draw 1 cubic foot of air is :—

$$N = \frac{28290}{V};$$

or if the capacity of the beaker is measured in grains :—

$$N = \frac{436485}{V}.$$

N will usually be a mixed number, but the nearest integral number is substituted, and it will be safest to substitute the next higher integral number. Thus, if N be found 9.3, it will be safest to consider 10 as the number of aspirations necessary to draw 1 cubic foot. The aspirator must be air-tight. The gas is withdrawn from the chimney through a glass tube, which should be sufficiently long to reach a considerable distance into the chimney, say 6 feet. The glass tube should be of at least $\frac{1}{2}$ in. diameter, otherwise the aspiration is tedious. In flues where the temperature is too high for glass, a porcelain tube may be employed. The bellows and tube are washed with distilled water until the washings give no reaction with silver nitrate. 100 or 200 cubic centimetres of distilled water, free from chloride, are then charged into the bellows, and after each aspiration the gas is well washed by shaking the contents of the aspirator violently. When the number N of aspirations has been made, some water is forced into the glass tube, and allowed to flow back into the bellows to wash out any acid which may have condensed in the tube. The liquid is then transferred into a porcelain dish (or into a beaker standing on a porcelain slab). If the liquid is so highly charged with soot that it would be impossible to recognise the change of colour, it must be filtered through a filter previously washed free from chlorides. The liquid is then oxidised by adding sufficient hydrogen peroxide to oxidise the sulphur dioxide to sulphuric acid; the total acidity is then determined by titration with standard alkali, using methyl orange as indicator. The chloride in the neutralised solution is then determined by titration with centinormal silver nitrate using potassium chromate as indicator.

Sometimes black or green precipitates are formed which render the endpoint a matter of uncertainty. The Alkali Inspectors recommend the following procedure to ensure freedom from "black" tests :—

After titration with sodium carbonate for total acidity, about 0.5 g. of calcium or magnesium carbonate is added, followed by 5 to 10 drops of ferric sulphate solution (5 per cent.); stir for one minute, decant and filter the solution, and titrate with centinormal silver nitrate in the usual way.

The "grains per cubic foot" in the gas is found by multiplying the cubic centimetres of centinormal silver nitrate solution used by 0.05633.

D.—Hydrochloric Acid.

1. SPECIFIC GRAVITY OF PURE HYDROCHLORIC ACID
AT 15° C. COMPARED WITH WATER AT 4°, AND
REDUCED TO VACUUM. (Lunge and Marchlewski.)

| Degrees Twaddell. | Specific Gravity at 15° 4° in vacuo. | 100 parts by weight correspond to parts by weight of | | | 1 litre contains g. of HCl. | 1 cubic foot contains lbs. of HCl. |
|----------------------|--|---|---|--|--------------------------------------|---|
| | | HCl. | Acid of spec. gravity 1.1425 = 28.5° Tw. | Acid of spec. gravity 1.152 = 30.4° Tw. | | |
| 0 | 1.000 | 0.16 | 0.57 | 0.53 | 1.6 | 0.10 |
| 1 | 1.005 | 1.15 | 4.08 | 3.84 | 12 | 0.75 |
| 2 | 1.010 | 2.14 | 7.60 | 7.14 | 22 | 1.37 |
| 3 | 1.015 | 3.12 | 11.80 | 10.41 | 32 | 1.99 |
| 4 | 1.020 | 4.13 | 14.67 | 13.79 | 42 | 2.62 |
| 5 | 1.025 | 5.15 | 18.30 | 17.19 | 53 | 3.30 |
| 6 | 1.030 | 6.15 | 21.85 | 20.58 | 64 | 3.99 |
| 7 | 1.035 | 7.15 | 25.40 | 23.87 | 74 | 4.61 |
| 8 | 1.040 | 8.16 | 28.99 | 27.24 | 85 | 5.30 |
| 9 | 1.045 | 9.16 | 32.55 | 30.58 | 96 | 5.98 |
| 10 | 1.050 | 10.17 | 36.14 | 33.95 | 107 | 6.67 |
| 11 | 1.055 | 11.18 | 39.73 | 37.33 | 118 | 7.35 |
| 12 | 1.060 | 12.19 | 43.32 | 40.70 | 129 | 8.04 |
| 13 | 1.065 | 13.19 | 46.87 | 44.04 | 141 | 8.79 |
| 14 | 1.070 | 14.17 | 50.35 | 47.31 | 152 | 9.48 |
| 15 | 1.075 | 15.16 | 53.87 | 50.62 | 163 | 10.16 |
| 16 | 1.080 | 16.15 | 57.39 | 53.92 | 174 | 10.85 |
| 17 | 1.085 | 17.13 | 60.87 | 57.19 | 186 | 11.59 |
| 18 | 1.090 | 18.11 | 64.35 | 60.47 | 197 | 12.28 |
| 19 | 1.095 | 19.06 | 67.73 | 63.64 | 209 | 13.03 |
| 20 | 1.100 | 20.01 | 71.11 | 66.81 | 220 | 13.71 |
| 21 | 1.105 | 20.97 | 74.52 | 70.01 | 232 | 14.46 |
| 22 | 1.110 | 21.92 | 77.89 | 73.19 | 243 | 15.15 |
| 23 | 1.115 | 22.86 | 81.23 | 76.32 | 255 | 15.90 |
| 24 | 1.120 | 23.82 | 84.64 | 79.53 | 267 | 16.65 |
| 25 | 1.125 | 24.78 | 88.06 | 82.74 | 278 | 17.38 |
| 26 | 1.130 | 25.75 | 91.60 | 85.97 | 291 | 18.14 |
| 27 | 1.135 | 26.70 | 94.88 | 89.15 | 303 | 18.89 |
| 28 | 1.140 | 27.66 | 98.29 | 92.35 | 315 | 19.64 |
| 29 | 1.145 | 28.61 | 101.67 | 95.52 | 328 | 20.45 |
| 30 | 1.150 | 29.57 | 105.08 | 98.73 | 340 | 21.20 |
| 31 | 1.155 | 30.55 | 108.58 | 102.00 | 353 | 22.01 |
| 32 | 1.160 | 31.52 | 112.01 | 105.24 | 366 | 22.82 |
| 33 | 1.165 | 32.49 | 115.46 | 108.48 | 379 | 23.68 |
| 34 | 1.170 | 33.46 | 118.91 | 111.71 | 392 | 24.44 |
| 35 | 1.175 | 34.42 | 122.32 | 114.92 | 404 | 25.19 |
| 36 | 1.180 | 35.39 | 125.76 | 118.16 | 418 | 26.06 |
| 37 | 1.185 | 36.31 | 129.03 | 121.28 | 430 | 26.81 |
| 38 | 1.190 | 37.23 | 132.30 | 124.30 | 443 | 27.62 |
| 39 | 1.195 | 38.16 | 135.61 | 127.41 | 456 | 28.48 |
| 40 | 1.200 | 39.11 | 138.98 | 130.58 | 469 | 29.24 |

2. INFLUENCE OF TEMPERATURE ON THE SPECIFIC GRAVITY OF HYDROCHLORIC ACID.

| 0°. | 5°. | 10°. | 15°. | 20°. | 25°. | 30°. | 35°. | 40°. | 45°. | 50°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·168 | 1·165 | 1·163 | 1·160 | 1·157 | 1·154 | 1·152 | 1·149 | 1·147 | 1·144 | 1·142 |
| 1·158 | 1·155 | 1·153 | 1·150 | 1·147 | 1·145 | 1·142 | 1·139 | 1·137 | 1·134 | 1·132 |
| 1·148 | 1·145 | 1·143 | 1·140 | 1·137 | 1·134 | 1·132 | 1·129 | 1·127 | 1·125 | 1·123 |
| 1·138 | 1·135 | 1·133 | 1·130 | 1·127 | 1·125 | 1·122 | 1·119 | 1·117 | 1·114 | 1·112 |
| 1·128 | 1·125 | 1·123 | 1·120 | 1·117 | 1·115 | 1·112 | 1·110 | 1·108 | 1·106 | 1·103 |
| 1·118 | 1·115 | 1·113 | 1·110 | 1·107 | 1·105 | 1·103 | 1·101 | 1·099 | 1·097 | 1·094 |
| 1·108 | 1·105 | 1·103 | 1·100 | 1·097 | 1·095 | 1·092 | 1·090 | 1·088 | 1·086 | 1·084 |
| 1·098 | 1·095 | 1·093 | 1·090 | 1·087 | 1·085 | 1·082 | 1·080 | 1·077 | 1·075 | 1·073 |
| 1·088 | 1·085 | 1·083 | 1·080 | 1·077 | 1·075 | 1·073 | 1·070 | 1·068 | 1·066 | 1·064 |
| 1·078 | 1·075 | 1·073 | 1·070 | 1·068 | 1·065 | 1·063 | 1·061 | 1·059 | 1·057 | 1·055 |
| 1·068 | 1·065 | 1·063 | 1·060 | 1·058 | 1·055 | 1·053 | 1·050 | 1·048 | 1·046 | 1·044 |
| 1·058 | 1·055 | 1·053 | 1·050 | 1·048 | 1·045 | 1·043 | 1·040 | 1·038 | 1·035 | 1·033 |
| 1·048 | 1·045 | 1·043 | 1·040 | 1·037 | 1·035 | 1·032 | 1·030 | 1·027 | 1·025 | 1·022 |
| 1·038 | 1·035 | 1·033 | 1·030 | 1·027 | 1·024 | 1·022 | 1·019 | 1·017 | 1·014 | 1·012 |
| 1·028 | 1·025 | 1·023 | 1·020 | 1·017 | 1·014 | 1·012 | 1·009 | 1·007 | 1·004 | 1·002 |
| 1·018 | 1·015 | 1·013 | 1·010 | 1·007 | 1·004 | 1·002 | 0·999 | 0·997 | 0·994 | 0·992 |
| | | | | | | | | | | |
| 55°. | 60°. | 65°. | 70°. | 75°. | 80°. | 85°. | 90°. | 95°. | 100°. | |
| 1·140 | 1·138 | 1·136 | 1·133 | 1·131 | 1·129 | 1·127 | 1·125 | 1·123 | 1·121 | |
| 1·130 | 1·128 | 1·126 | 1·123 | 1·121 | 1·119 | 1·116 | 1·114 | 1·112 | 1·110 | |
| 1·120 | 1·118 | 1·116 | 1·113 | 1·111 | 1·108 | 1·106 | 1·104 | 1·102 | 1·099 | |
| 1·109 | 1·107 | 1·104 | 1·102 | 1·100 | 1·097 | 1·095 | 1·093 | 1·090 | 1·088 | |
| 1·101 | 1·099 | 1·096 | 1·094 | 1·091 | 1·089 | 1·086 | 1·084 | 1·081 | 1·079 | |
| 1·093 | 1·090 | 1·088 | 1·085 | 1·083 | 1·080 | 1·078 | 1·075 | 1·073 | 1·070 | |
| 1·082 | 1·080 | 1·078 | 1·076 | 1·073 | 1·071 | 1·069 | 1·066 | 1·064 | 1·061 | |
| 1·071 | 1·069 | 1·067 | 1·065 | 1·063 | 1·061 | 1·059 | 1·057 | 1·055 | 1·053 | |
| 1·062 | 1·060 | 1·058 | 1·056 | 1·054 | 1·053 | 1·051 | 1·049 | 1·047 | 1·045 | |
| 1·053 | 1·051 | 1·049 | 1·048 | 1·046 | 1·044 | 1·043 | 1·041 | 1·039 | 1·037 | |
| 1·042 | 1·040 | 1·038 | 1·036 | 1·034 | 1·033 | 1·031 | 1·029 | 1·027 | 1·025 | |
| 1·031 | 1·029 | 1·027 | 1·025 | 1·023 | 1·021 | 1·019 | 1·017 | 1·015 | 1·013 | |
| 1·020 | 1·018 | 1·016 | 1·014 | 1·011 | 1·009 | 1·007 | 1·005 | 1·003 | 1·001 | |
| 1·010 | 1·008 | 1·005 | 1·003 | 1·001 | 0·999 | 0·997 | 0·995 | 0·993 | 0·991 | |
| 1·000 | 0·998 | 0·995 | 0·993 | 0·991 | 0·989 | 0·987 | 0·985 | 0·983 | 0·981 | |
| 0·990 | 0·988 | 0·985 | 0·983 | 0·981 | 0·979 | 0·977 | 0·975 | 0·973 | 0·971 | |

3. ANALYSIS OF HYDROCHLORIC ACID.

(a) *Estimation of HCl.*—Measure off, by means of an accurate pipette, 10 c.c. of the acid, the specific gravity of which should be known, dilute to 200 c.c., take out 10 c.c. Or else employ a glass-tap pipette, as described on p. 172 for fuming sulphuric acid; in this case its contents are run into water and employed directly for

titration. Add sodium carbonate, free from chloride, till the reaction is neutral or faintly alkaline. This point will be hit quickly, and without the loss of many drops for testing, if the percentage of the acid is ascertained from its specific gravity by the table (p. 178) and the corresponding quantity of sodium carbonate solution is run in from a burette. Now add a little neutral potassium chromate, and titrate with decinormal silver solution till a faint pink colour is produced (*cf.* p. 174). Deduct 0.2 c.c. from the silver solution employed; the remainder, multiplied by 72.94 and divided by the specific gravity of the acid, indicates its percentage of HCl. This test would fail in the presence of metallic chlorides, which are, however, hardly ever present in appreciable quantity in ordinary hydrochloric acid. The free HCl can also be ascertained by estimating the total acidity and deducting therefrom that due to sulphuric acid, making allowance for any sodium sulphate present.

(b) *Estimation of Sulphuric Acid*.—Neutralise the acid almost, but not quite, with sodium carbonate free from sulphate, and precipitate the sulphuric acid by barium chloride, as on p. 134. If the acid be partially saturated with NH_3 , or not saturated at all, the result is too low. Each part of BaSO_4 is equal to 0.3430SO_3 .

(c) *Estimation of Iron*.—Reduce this to ferrous iron by digesting the acid for a short time with a rod of zinc free from iron, wash the rod, dilute the whole with water, add some manganous chloride or sulphate (in order to counteract the action of HCl on permanganate), and titrate with a twentieth normal solution of potassium permanganate, each cubic centimetre of which indicates 0.002792 g. Fe. In case of SO_2 being present, this must first be oxidised to sulphuric acid, before reducing the ferric salt and titrating.

(d) *Free Chlorine*.—Introduce a sample of the acid into a flask, remove the air from the empty space by CO_2 ; shake the acid with a strip of clean metallic copper. The latter is converted into chloride by the free chlorine, and the copper thus dissolved can be detected by potassium ferrocyanide, etc. This will show the smallest traces of chlorine. For ordinary purposes it is sufficient to heat the acid gently and hold a strip of KI starch paper in the vapour; this will at once turn blue in the presence of free Cl.

(e) *Sulphur Dioxide*.—Oxidise with permanganate, or iodine, or H_2O_2 to sulphuric acid, estimate the total H_2SO_4 now present as in No. 2, and deduct the quantity there found; the remainder = SO_2 .

(f) *Arsenic*.—Reduce all to trichloride by passing in SO_2 for some time, and precipitate by H_2S as As_2S_3 . Wash the precipitate, dissolve it on the filter in ammonia, evaporate the solution in a glass or porcelain dish, dry at 100° , and weigh. One part As_2S_3 = 0.6091 As = 0.8041 As_2O_3 .

VI. BLEACHING POWDER AND CHLORATE OF POTASH MANUFACTURE.

A.—Natural Manganese Ore.

1. *Manganese Dioxide*.—Weigh 1.0866 g. of manganese ore, ground as fine as possible, and dried for some time at 100°C .; put it into the flask (Fig. 15) closed by a rubber (Bunsen) valve, or, preferably, into a flask provided with a Contat-Göckel bulb (Fig. 16), which has been half-filled with a concentrated solution of sodium carbonate; put into the flask 75 c.c. (in three portions with a 25 c.c. pipette) of a solution containing

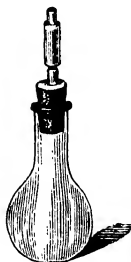


FIG. 15.

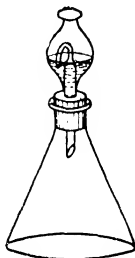


FIG. 16.

100 g. pure crystallised ferrous sulphate and 100 c.c. pure concentrated sulphuric acid, diluted to 1 litre, and standardised on the same day by means of the same 25 c.c. pipette, with decinormal potassium permanganate. Close the flask with its cork or valve, and heat till the manganese is completely decomposed, leaving a light-coloured residue. On cooling, the valve must act properly, which will be seen by the collapsing of the rubber tube, Fig. 15, or by the running in of sodium carbonate solution, Fig. 16. After complete cooling add 200 c.c. of water, and titrate with potassium permanganate to a faint pink coloration. Deduct the quantity of permanganate required from that corresponding to the 75 c.c. of iron solution; the remainder indicates for each cubic centimetre 0.02173 g., equal to 2 per cent. MnO_2 .

2. *Carbon Dioxide* is estimated gravimetrically by expelling it with dilute sulphuric or nitric acid and absorbing it with soda-lime, by means of the apparatus and process described fully in Cumming and Kay's *Quantitative Analysis* (5th Edition), pp. 215 and 219.

3. *Estimation of the Hydrochloric Acid required for Decomposing the Ore*.—Dissolve 1 g. of manganese ore in a flask provided

with a reflux condenser in 10 c.c. of ordinary strong hydrochloric acid the titre of which is known, employing heat as far as necessary. Allow the solution to cool, and add standard alkali till reddish-brown flakes of ferric hydroxide appear, which do not redissolve on agitation. Calculate the standard alkali corresponding to the acid employed for dissolving the ore, and deduct the quantity thus found from the 10 c.c. first employed.

B.—Recovered Manganese Mud and Weldon Liquors.

1. *MnO₂ in Weldon Mud.*—Standardise an acid iron solution (100 g. pure crystallised ferrous sulphate + 100 c.c. pure concentrated sulphuric acid in 1 litre) by seminormal potassium permanganate, by diluting 25 c.c. of the former with 100 c.c. or 200 c.c. of cold water, and adding the permanganate from a stopcock burette, till, on agitating, the pink colour is not discharged immediately, but remains at least for half a minute. Subsequent decolorisation is not taken into account. This test should be made once each day. Call the cubic centimetres of permanganate employed x . Now, put another 25 c.c. of the iron solution into a beaker. Take 10 c.c. of manganese mud out of the well-shaken bottle (mere stirring does not ensure a proper mixture) containing it; wash the pipette outside, run its contents into the beaker containing the iron solution, and wash the mud remaining inside into the same beaker. When all has dissolved, on agitating, add 100 c.c. of water, and titrate by potassium permanganate. The number of cubic centimetres now used we call y . The quantity of MnO₂ in grams per litre of mud equals $2.173 (x - y)$.

2. *Total Manganese of the Mud, expressed in Grams of theoretically possible MnO₂ per Litre.*—Take 10 c.c. of the mud, with the same precautions as in test No. 1. Boil with strong hydrochloric acid till all chlorine is driven off; saturate the excess of acid by ground marble or precipitated calcium carbonate; add a concentrated filtered solution of bleaching powder; boil a few minutes till the colour turns a decided pink, and the excess of bleaching powder can be smelt, and again destroy the pink colour by adding alcohol drop by drop. All manganese is now present as MnO₂; filter and wash. The filtrate should not produce any brown colour with a bleaching-powder solution, which would show the presence of Mn in solution. Continue the washing till starch and KI do not give any reaction. Transfer the filter with the precipitate into 25 c.c. of the acid iron solution employed in test No. 1. If all MnO₂ is not dissolved, add another 25 c.c. of iron solution; dilute with 100 c.c. of water, and titrate with permanganate. Calculation as in No. 1.

3. *Estimation of the "Base," i.e. the Monoxides, etc., of the Mud which combine with HCl without yielding Free Chlorine.*—Dilute 25 c.c., or in case of a very rich base 50 c.c., of normal oxalic acid (63.03 g. crystallised oxalic acid in 1 litre) to 100 c.c.; heat to 60°–80° C., add 10 c.c. manganese mud by means of a pipette, with the precautions stated in No. 1, and agitate till the colour of the precipitate is no longer yellowish but pure white, which ought to take place very soon at the above temperature. Dilute to 202 c.c. (2 c.c. correspond to the volume of the precipitate, and are marked on the neck of the 200 c.c. flask); pour through a dry filter, and titrate 100 c.c. of the filtrate with standard alkali, employing phenolphthalein as indicator. (Methyl orange is not applicable for oxalic acid.) Call the number of cubic centimetres of standard alkali used, z . The oxalic acid serves (1) for reducing the MnO_2 with formation of MnO and CO_2 ; (2) for saturating the MnO thus formed; (3) for saturating the monoxides originally present, i.e. the base. The oxalic acid not thus used is equal to $2z$. The acid used for reducing MnO_2 is equal to that used for neutralising the MnO formed, and both amounts together are equal to the value $x-y$ obtained by the MnO_2 test, since the oxalic acid is normal and the permanganate half normal. The amount of oxalic acid consumed by the bases of the mud is found by deducting from the total acid used that required for the MnO_2 ($x-y$), and that which was not neutralised at all by the mud $= 2z$, therefore in all $x-y-2z$. The "base" is equal to the ratio of this value to that found in test No. 1, viz., $\frac{x-y}{2}$.

It is, therefore, if 25 c.c. of oxalic acid had been employed, equal to:

$$\frac{50 - 2x - 4z + 2y}{x-y} = \left(\frac{50 - 4z}{x-y} \right) - 2;$$

or, if 50 c.c. had been employed, equal to:—

$$\left(\frac{100 - 4z}{x-y} \right) - 2.$$

C.—Limestone.

1. *Insoluble Matter.*—Dissolve 1 g. in hydrochloric acid, filter the residue, wash, dry, and ignite. In the presence of appreciable quantities of organic matter, weigh the filter after drying at 100°, and ignite afterwards. The difference is calculated as organic matter.

2. *Lime.*—Dissolve 1 g. in 25 c.c. normal hydrochloric acid and titrate with normal alkali. Deduct the volume of the latter used from 25 and multiply the remainder by 2.8 to find the percentage of CaO , or by 5 to find that of CaCO_3 . (*N.B.*—Here

MgO is calculated as CaO. This is admissible for most limestones employed in alkali and bleaching-powder making, because they contain but little MgO; otherwise the MgO or MgCO_3 found as in No. 3 must be deducted.)

3. *Magnesia* need only be estimated in limestone used for manganese recovery. Dissolve 2 g. of limestone in HCl, precipitate the CaO by NH_3 and ammonium oxalate, and precipitate the magnesia in the filtrate by sodium phosphate (*cf.* p. 175).

4. *Iron* is usually estimated only in limestone used for bleaching-powder making. Dissolve 2 g. in HCl, reduce by zinc, dilute, add some manganese solution free from iron, and titrate by permanganate (*cf.* p. 170).

D.—Quicklime.

1. *Free CaO*.—Weigh 100 g. of an average sample carefully taken, slake it completely, put the milk into a half-litre flask, fill up to the mark, shake well, take 100 c.c. out, run it into a half-litre flask, fill up, mix well, and employ 25 c.c. of the contents, equal to 1 g. quicklime, for the test. Titrate by normal oxalic acid and phenolphthalein as indicator, adding the acid *very slowly* and shaking well after each addition. The colour is changed when all free lime has been saturated and before the CaCO_3 is attacked. One c.c. normal HCl = 0.02804 g. CaO.

2. *Carbon Dioxide*.—Titrate CaO and CaCO_3 together by dissolving in an excess of standard hydrochloric acid and titrating back with standard alkali. By deducting the CaO estimated as in No. 1 the quantity of CaCO_3 is obtained. For very accurate estimations the CO_2 is expelled by HCl, absorbed in soda-lime, and weighed. (See Cumming and Kay's *Quantitative Analysis*, (5th Edition), pp. 215 and 219.)

E.—Slaked Lime.

1. *Water*.—Weigh about 1 g. in a stoppered glass tube, and heat it gradually in a platinum crucible, at last to a strong red heat (*cf.* p. 174); allow to cool in the exsiccator, and weigh. The loss of weight is equal to $\text{H}_2\text{O} + \text{CO}_2$.

2. *Carbon Dioxide* is estimated as above in D, 2.

3. *Estimation of the percentage of Caustic Lime in Milk of Lime by means of the specific gravity* (Blattner).—Thin milk of lime is poured into the cylinder and the reading of the hydrometer is taken quickly, before the lime subsides. For thick milk of lime employ a somewhat wide cylinder, put the hydrometer in without using any force and turn the cylinder slowly round, so that it receives a slight shaking, until the hydrometer ceases to sink. The following table is from Blattner's data for 15°.

TABLE SHOWING AMOUNT OF LIME IN MILK OF LIME.

| Degrees Twaddell. | Grms. CaO per litre. | Lbs. CaO per cubic foot. | Degrees Twaddell. | Grms. CaO per litre. | Lbs. CaO per cubic foot. |
|-------------------|----------------------|--------------------------|-------------------|----------------------|--------------------------|
| 2 | 11.7 | 0.7 | 28 | 177 | 11.1 |
| 4 | 24.4 | 1.5 | 30 | 190 | 11.9 |
| 6 | 37.1 | 2.3 | 32 | 203 | 12.7 |
| 8 | 49.8 | 3.1 | 34 | 216 | 13.5 |
| 10 | 62.5 | 3.9 | 36 | 229 | 14.3 |
| 12 | 75.2 | 4.7 | 38 | 242 | 15.1 |
| 14 | 87.9 | 5.5 | 40 | 255 | 15.9 |
| 16 | 100 | 6.3 | 42 | 268 | 16.7 |
| 18 | 113 | 7.1 | 44 | 281 | 17.6 |
| 20 | 126 | 7.9 | 46 | 294 | 18.4 |
| 22 | 138 | 8.7 | 48 | 307 | 19.2 |
| 24 | 152 | 9.5 | 50 | 321 | 20.0 |
| 26 | 164 | 10.3 | | | |

The editor would recommend that a table similar to the above be made by each user for his own use. Widely different results were obtained using lime from different sources.

F.—Bleaching Powder.

1. *Available Chlorine (Penot's Method).*—Weigh 7.092 g. of the sample, previously well mixed; grind it with a little water in a porcelain mortar (the lip of which has been greased a little underneath) till a completely homogeneous thin paste has been obtained; dilute with more water, wash the whole into a litre flask, fill up to the mark, and take for each test 50 c.c. = 0.3546 g. bleaching powder, having shaken up the flask immediately before. Run into the above, with continuous agitation, an alkaline decinormal arsenite solution, containing 4.948 g. As_2O_3 per litre till the expected point is not very far off. Then place a drop of the mixture on to a piece of filter paper, moistened with a starch solution containing potassium iodide. If there is very much chlorine left, a brown spot will be produced; if less chlorine, the spot will be blue. According to the depth of this colour more or less arsenite solution is run in, and the above test is repeated till the paper is coloured hardly perceptibly, or not at all. Each cubic centimetre of the arsenite solution indicates 1 per cent. available chlorine.

2. *Comparison of the Percentage of Bleaching Powder with the French (Gay-Lussac) Degrees.*—The latter are understood to mean the number of litres of chlorine gas at 0° C. and 760 mm. pressure which can be given off by 1 kilogram of bleaching powder.

| French Degrees | Per cent. Chlorine. | French Degrees. | Per cent. Chlorine. | French Degrees. | Per cent. Chlorine. | French Degrees. | Per cent. Chlorine. |
|----------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|
| 63 | 20·28 | 81 | 26·07 | 99 | 31·87 | 116 | 37·34 |
| 64 | 20·60 | 82 | 26·40 | 100 | 32·10 | 117 | 37·66 |
| 65 | 20·92 | 83 | 26·72 | 101 | 32·51 | 118 | 37·99 |
| 66 | 21·25 | 84 | 27·04 | 102 | 32·83 | 119 | 38·31 |
| 67 | 21·57 | 85 | 27·31 | 103 | 33·16 | 120 | 38·63 |
| 68 | 21·89 | 86 | 27·36 | 104 | 33·48 | 121 | 38·95 |
| 69 | 22·21 | 87 | 28·01 | 105 | 33·80 | 122 | 39·27 |
| 70 | 22·55 | 88 | 28·33 | 106 | 34·12 | 123 | 39·51 |
| 71 | 22·86 | 89 | 28·65 | 107 | 34·47 | 124 | 39·92 |
| 72 | 23·18 | 90 | 28·97 | 108 | 34·78 | 125 | 40·24 |
| 73 | 23·50 | 91 | 29·29 | 109 | 35·09 | 126 | 40·56 |
| 74 | 23·82 | 92 | 29·62 | 110 | 35·41 | 127 | 40·88 |
| 75 | 24·14 | 93 | 29·94 | 111 | 35·73 | 128 | 41·20 |
| 76 | 24·47 | 94 | 30·26 | 112 | 36·05 | 129 | 41·53 |
| 77 | 24·79 | 95 | 30·53 | 113 | 36·38 | 130 | 41·85 |
| 78 | 25·11 | 96 | 30·90 | 114 | 36·70 | 131 | 42·17 |
| 79 | 25·40 | 97 | 31·23 | 115 | 37·02 | 132 | 42·49 |
| 80 | 25·75 | 98 | 31·55 | | | | |

3. Testing the Atmosphere of the Chambers for Chlorine before opening them.—In England a maximum of $2\frac{1}{2}$ grains chlorine per cubic foot is pre-

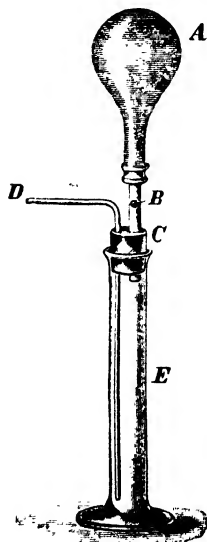


FIG. 17.

scribed before the chamber may be opened. This is ascertained by the apparatus, Fig. 17. A is a rubber pressure ball holding about 100 c.c., B a hole in its mouthpiece, D a glass tube reaching nearly to the bottom of the glass jar E; its lower end is contracted so that only a thin needle can pass through. E is charged with 25 c.c. of a solution, so prepared that ten bulbfuls (A) of gas containing $2\frac{1}{2}$ grains of chlorine per cubic foot will just colour the liquid by separation of iodine. The content of the chamber gas in grains of chlorine per cubic foot is inversely as the number of bulbfuls required to colour the solution. The solution is prepared by diluting 64·0 c.c. of decinormal sodium arsenite solution (see p. 115), adding 25 g. potassium iodide, 5 g. precipitated calcium carbonate, 6 to 10 drops of ammonia, and diluting the whole to 1 litre. For a test, take 25 c.c. of this solution, add a little starch solution, introduce the outer end of D into the bleaching powder chamber 2 feet above the bottom, compress A and close the hole B by a finger, whereupon the pressure on A is

close the hole B by a finger, whereupon the pressure on A is

relieved. By the expansion of the rubber ball A chamber air is aspirated into the liquid contained in E. Note the number of times the ball A must be employed as described, before the liquid is coloured by the separation of iodine. According to the prescribed limit, this number should be at least 10.

A more accurate method for determining the chlorine is given in Lunge-Keane, *Techn. Methods*, vol. i. (2nd Edition), p. 597.

G.—Electrolytic Chlorine.

Examination for Carbon Dioxide.—Chlorine gas produced by means of gas carbon electrodes may contain up to 12 per cent. carbon dioxide. This CO_2 is estimated by Ferchland's process, as modified in Lunge's laboratory.

A dry Bunte burette, the content of which (from tap to tap = v) is exactly known, is filled with the chlorine by passing this through for some time, the gas passing in from below, so as to rise regularly below the lighter air. When filled with the chlorine gas under atmospheric pressure, the burette is fixed in a clamp in a vertical position, and a level tube is attached by means of a strong rubber tube, filled with mercury to the bottom tap, which has a single bore. The rubber tube must be entirely filled with mercury, so that no air can get into the burette, and it is secured against slipping off by iron wire. When the bottom tap of the burette is opened, mercury enters into the burette and absorbs the chlorine, at first rather quickly, but later on its surface is covered by a pellicle, which precludes further action. Then the bottom tap is closed, and by agitating the burette the complete absorption of the chlorine is effected. The sides of the burette are thereby covered with a non-transparent layer, and a mixture of mercurous chloride and mercury floats on the top of the mercury, which prevent reading off the volume. When the absorption of the chlorine is finished, open the bottom tap, put the level of the mercury approximately equal in the burette and the level tube, and allow ten or fifteen minutes for the equalisation of the temperature. Now put 1 c.c. saturated solution of sodium chloride into the top beaker, and allow this to enter the burette by lowering the level tube. This causes the pulverulent mixture on the top of the mercury to subside, and an easily readable surface to be formed. Then adjust the levels for atmospheric pressure, as described in the case of the nitrometer (p. 165) and read the volume of gas = a . Now introduce a little concentrated solution of potassium hydroxide through the funnel into the burette, absorb the CO_2 by shaking, re-establish atmospheric

**PRESSURE AND SPECIFIC GRAVITY OF LIQUID
CHLORINE. (Knietzsch).**

| Temperature. | Pressure. | Specific Gravity. | Mean coefficient of expansion. |
|--------------|--------------|-------------------|-----------------------------------|
| -88° | 37.5 mm. Hg. | ... | 0.001409 |
| -85 | 45.0 " | ... | |
| -80 | 62.5 " | 1.6602 | |
| -75 | 88.0 " | 1.6490 | |
| -70 | 118 " | 1.6382 | |
| -65 | 159 " | 1.6273 | |
| -60 | 210 " | 1.6167 | |
| -55 | 275 " | 1.6055 | |
| -50 | 350 " | 1.5945 | |
| -45 | 445 " | 1.5830 | |
| -40 | 560 " | 1.5720 | |
| -35 | 705 " | 1.5589 | |
| -33.6 | 760 " | 1.5575 | |
| -30 | 1.20 atm. | 1.5485 | 0.001793 |
| -25 | 1.50 " | 1.5358 | |
| -20 | 1.84 " | 1.5230 | |
| -15 | 2.23 " | 1.5100 | |
| -10 | 2.63 " | 1.4965 | |
| -5 | 3.14 " | 1.4830 | |
| ± 0 | 3.66 " | 1.4690 | |
| +5 | 4.25 " | 1.4548 | 0.001978 |
| +10 | 4.95 " | 1.4405 | |
| +15 | 5.75 " | 1.4273 | 0.002030 |
| +20 | 6.62 " | 1.4118 | |
| +25 | 7.63 " | 1.3984 | 0.002190 |
| +30 | 8.75 " | 1.3815 | |
| +35 | 9.95 " | 1.3683 | 0.002260 |
| +40 | 11.50 " | 1.3510 | |
| 50 | 14.70 " | 1.3170 | 0.002690 |
| 60 | 18.60 " | 1.2930 | |
| 70 | 23.00 " | 1.2430 | 0.003460 |
| 80 | 28.40 " | 1.2000 | |
| 90 | 34.50 " | | |
| 100 | 41.70 " | | |
| 110 | 50.80 " | | |
| 120 | 60.40 " | | |
| 130 | 71.60 " | | |
| 146 | 98.50 " | Critical Point | |

pressure, and read the new volume of gas = b . The formula $\frac{(a-b) 100}{v}$ shows the percentage of CO_2 in the crude chlorine gas.

No correction for vapour tension of water need be made in this case if concentrated solutions have been used.

H.—Chlorate of Potash.

1. *Chlorate Liquors* contain calcium chlorate and chloride, but these are calculated as potassium salts for the sake of convenience.

(a) *Chlorate* is estimated both in order to check the work and to calculate the necessary addition of KCl . Measure 2 c.c. of liquor in an accurate pipette, run it into a flask (Fig. 15, p. 181, add a little hot water and one drop of alcohol, boil (without the valve) till all smell of chlorine and the pink colour have disappeared, allow to cool, add 25 c.c. of the strongly acid ferrous sulphate solution (cf. p. 181, and requiring a c.c. of seminormal permanganate), close the flask with its valve, and boil for ten minutes. After cooling, titrate with seminormal permanganate. The number of cubic centimetres required to produce a faint pink = b . The liquor then contains calcium chlorate equivalent to $5.105 (a-b)$ g. KClO_3 per litre, and it will theoretically require an amount of $3.106 (a-b)$ g. of pure KCl per litre.

(b) *Chloride* is estimated in order to check the work, and is therefore calculated as KCl , although present as CaCl_2 . Treat 1 c.c. of liquor as above, to destroy the free chlorine and pink colour, allow to cool, add a little neutral potassium chromate, and titrate with decinormal silver nitrate (as described p. 174). Each cubic centimetre of the latter indicates chloride equivalent to 7.456 g. KCl per litre.

2. *Commercial Chlorate of Potash* is only tested for chlorides, calculated as KCl . As their quantity is very small, it is advisable to dissolve 50 g. of the salt in water absolutely free from chlorine, and to test with decinormal silver nitrate, as in 1 (b). Each cubic centimetre of this solution = 0.007456 g. KCl = 0.015 per cent. KCl .

I.—Bleach Liquors.

These are tested like Bleaching Powder, p. 185.

Electrolytic Bleach Liquor, see p. 209.

VII.—ANALYSIS OF COMMERCIAL SODA ASH.

When merely the *available alkali* (alkalimetric degree) has to be ascertained, it is convenient to weigh out 15.5 g., to dissolve in a 500 c.c. flask, and to take for each test 50 c.c. (in Germany, without filtering; in England, sometimes with, sometimes without). In this case each cubic centimetre of standard acid indicates 0.03100 g. Na_2O , or just 2 per cent. of available alkali (Na_2O). The standard acid is normal hydrochloric acid, containing 36.468 g. HCl per litre, and is standardised both with pure sodium carbonate and with silver nitrate. The indicator is either litmus (in which case the solution has to be boiled for some time) or more conveniently methyl orange (which is used with cold solutions).

If the percentage of alkali is to be calculated in terms of Na_2CO_3 , as is usual in Germany and other countries, 2.6500 g. is weighed out, dissolved, and titrated (without filtering) with normal hydrochloric acid, each c.c. of which indicates 2 per cent. Na_2CO_3 in this case. In Germany the samples are ignited before weighing, and the percentage is always stated for soda ash in this dry state.

For a *complete* analysis of commercial soda ash 50 g. are dissolved in warm water.

1. *The Insoluble Residue* is filtered and washed, the filtrate and washings are diluted up to 1 litre, and the following tests are made with this solution.

2. *Sodium Carbonate* is found by titrating 20 c.c. (equal to 1 g. of soda ash) with normal HCl , deducting the amount of No. 3. That of No. 4 is always too small to consider in this case.

3. *Sodium Hydroxide* is estimated by adding to 50 c.c. of the solution, contained in a 100 c.c. flask, an excess of barium chloride. Add water to 100 c.c. and allow precipitate to settle. Take 50 c.c., without filtering, and titrate with standard acid (e.g., decinormal hydrochloric acid), using methyl orange as indicator.

4. *Sodium Sulphide*.—100 c.c. (equal to 5 g. of ash) are titrated with ammoniacal silver nitrate containing 13.818 g. Ag per litre, and indicating 0.005 g. Na_2S per cubic centimetre. Heat the soda liquor to boiling, add ammonia, and run in the silver solution from a burette divided in $\frac{1}{10}$ c.c., till no further black precipitate of Ag_2S is produced. In order to observe this more accurately the liquid is filtered towards the end of the operation, and the titration is continued if necessary. This filtration is repeated several times. Each cubic centimetre of silver solution indicates 0.1 per cent. of Na_2S in the alkali.

5. *Sodium Sulphite*.—Acidulate 100 c.c. (equal to 5 g. soda ash) with acetic acid, add starch solution, and titrate with iodine till a blue colour appears. A decinormal iodine solution corresponds to 0.006304 g. Na_2SO_3 per cubic centimetre (in this case 0.126 per cent.). From this should be deducted the amount corresponding to test No. 4; 1 c.c. of the silver solution can be regarded as equal to 1.3 c.c. of the decinormal, or equal to 5.0 c.c. of the weaker iodine solution.

6. *Sodium Sulphate*.—Acidulate 20 c.c. of the solution (equal to 1 g. soda ash) with hydrochloric acid, precipitate with barium chloride, as on p. 134, and weigh the BaSO_4 , of which 1.000 part is equal to 0.6086 part Na_2SO_4 .

7. *Sodium Chloride*.—Neutralise 20 c.c. (equal to 1 g. soda ash) exactly with nitric acid, preferably by adding exactly as many cubic centimetres normal nitric acid from a burette as had been used in test No. 1; then add neutral potassium chromate, and titrate with decinormal silver nitrate as described on p. 174. Each cubic centimetre of this corresponds to 0.005846 g. NaCl .

8. *Iron*.—Neutralise 100 c.c. (equal to 5 g. soda ash) with sulphuric acid free from iron, reduce with zinc free from iron (p. 170), and titrate with $\frac{1}{20}$ normal potassium permanganate, of which each cubic centimetre corresponds to 0.002793 g. Fe , or in this case 0.0559 per cent. Fe .

9. *Sodium Silicate* is not present in appreciable quantities in ordinary soda ash, but always in the ash recovered from the liquor used in the manufacture of wood "cellulose." It is estimated by acidulating 20 c.c. (equal to 1 g. soda ash) with HCl , filtering the SiO_2 , drying, and igniting. 1 g. $\text{SiO}_2 = 2.028$ g. Na_2SiO_3 .

10. *Table for comparing French, German, and English Commercial Alkalimetric Degrees*.—The French or Descroizilles degrees mean the quantity of real sulphuric acid, H_2SO_4 , neutralised by 100 parts of soda ash. The German degrees express the available alkali in terms of sodium carbonate, Na_2CO_3 . In England some works invoice in actual percentage of soda, Na_2O , as found in the first column of the following tables. The Newcastle test is based on the equivalent 32 for Na_2O , or 59.26 degrees for pure Na_2CO_3 , and invoices fractions of degrees.

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FRENCH, GERMAN, AND ENGLISH COMMERCIAL ALKALIMETRICAL DEGREES.

| Real Soda. Na ₂ O. | German degrees. Na ₂ CO ₃ . | New-castle degrees. | French degrees. | Real Soda. Na ₂ O. | German degrees. Na ₂ CO ₃ . | New-castle degrees. | French degrees. |
|----------------------------------|--|---------------------|-----------------|----------------------------------|--|---------------------|-----------------|
| 0.5 | 0.86 | 0.51 | 0.79 | 20.5 | 35.06 | 20.77 | 32.40 |
| 1 | 1.71 | 1.01 | 1.58 | 21 | 35.91 | 21.27 | 33.19 |
| 1.5 | 2.57 | 1.52 | 2.37 | 21.5 | 36.77 | 21.78 | 33.98 |
| 2 | 3.42 | 2.03 | 3.16 | 22 | 37.62 | 22.29 | 34.77 |
| 2.5 | 4.28 | 2.54 | 3.95 | 22.5 | 38.48 | 22.80 | 35.56 |
| 3 | 5.13 | 3.04 | 4.74 | 23 | 39.33 | 23.30 | 36.35 |
| 3.5 | 5.99 | 3.55 | 5.53 | 23.5 | 40.19 | 23.81 | 37.14 |
| 4 | 6.84 | 4.05 | 6.32 | 24 | 41.04 | 24.31 | 37.93 |
| 4.5 | 7.70 | 4.56 | 7.11 | 24.5 | 41.90 | 24.82 | 38.72 |
| 5 | 8.55 | 5.06 | 7.90 | 25 | 42.75 | 25.32 | 39.51 |
| 5.5 | 9.41 | 5.57 | 8.69 | 25.5 | 43.61 | 25.83 | 40.30 |
| 6 | 10.26 | 6.08 | 9.48 | 26 | 44.46 | 26.34 | 41.09 |
| 6.5 | 11.12 | 6.59 | 10.27 | 26.5 | 45.32 | 26.85 | 41.88 |
| 7 | 11.97 | 7.09 | 11.06 | 27 | 46.17 | 27.35 | 42.67 |
| 7.5 | 12.83 | 7.60 | 11.85 | 27.5 | 47.03 | 27.86 | 43.46 |
| 8 | 13.68 | 8.10 | 12.64 | 28 | 47.88 | 28.36 | 44.25 |
| 8.5 | 14.54 | 8.61 | 13.43 | 28.5 | 48.74 | 28.87 | 45.04 |
| 9 | 15.39 | 9.12 | 14.22 | 29 | 49.59 | 29.38 | 45.83 |
| 9.5 | 16.25 | 9.63 | 15.01 | 29.5 | 50.45 | 29.89 | 46.62 |
| 10 | 17.10 | 10.13 | 15.81 | 30 | 51.30 | 30.39 | 47.42 |
| 10.5 | 17.96 | 10.64 | 16.60 | 30.5 | 52.16 | 30.90 | 48.21 |
| 11 | 18.81 | 11.14 | 17.39 | 31 | 53.01 | 31.41 | 49.00 |
| 11.5 | 19.67 | 11.65 | 18.18 | 31.5 | 53.87 | 31.91 | 49.79 |
| 12 | 20.52 | 12.17 | 18.97 | 32 | 54.72 | 32.42 | 50.58 |
| 12.5 | 21.38 | 12.68 | 19.76 | 32.5 | 55.58 | 32.92 | 51.37 |
| 13 | 22.23 | 13.17 | 20.55 | 33 | 56.43 | 33.43 | 52.16 |
| 13.5 | 23.09 | 13.68 | 21.34 | 33.5 | 57.29 | 33.94 | 52.95 |
| 14 | 23.94 | 14.18 | 22.13 | 34 | 58.14 | 34.44 | 53.74 |
| 14.5 | 24.80 | 14.69 | 22.92 | 34.5 | 59.00 | 34.95 | 54.53 |
| 15 | 25.65 | 15.19 | 23.71 | 35 | 59.85 | 35.46 | 55.32 |
| 15.5 | 26.51 | 15.70 | 24.50 | 35.5 | 60.71 | 35.96 | 56.11 |
| 16 | 27.36 | 16.21 | 25.29 | 36 | 61.56 | 36.47 | 56.90 |
| 16.5 | 28.22 | 16.73 | 26.08 | 36.5 | 62.42 | 36.98 | 57.69 |
| 17 | 29.07 | 17.22 | 26.87 | 37 | 63.27 | 37.48 | 58.48 |
| 17.5 | 29.93 | 17.73 | 27.66 | 37.5 | 64.13 | 37.98 | 59.27 |
| 18 | 30.78 | 18.23 | 28.45 | 38 | 64.98 | 38.50 | 60.06 |
| 18.5 | 31.64 | 18.74 | 29.24 | 38.5 | 65.84 | 39.00 | 60.85 |
| 19 | 32.49 | 19.25 | 30.03 | 39 | 66.69 | 39.51 | 61.64 |
| 19.5 | 33.35 | 19.76 | 30.82 | 39.5 | 67.55 | 40.02 | 62.43 |
| 20 | 34.20 | 20.26 | 31.61 | 40 | 68.40 | 40.52 | 63.22 |

FRENCH, GERMAN, AND ENGLISH COMMERCIAL ALKALI-METRICAL DEGREES—*Continued.*

| Real Soda. Na ₂ O. | German degrees. Na ₂ CO ₃ . | New-castle degrees. | French degrees. | Real Soda. Na ₂ O. | German degrees. Na ₂ CO ₃ . | New-castle degrees. | French degrees. |
|----------------------------------|--|---------------------|-----------------|----------------------------------|--|---------------------|-----------------|
| 40·5 | 69·26 | 41·03 | 64·01 | 60·5 | 103·46 | 61·30 | 95·63 |
| 41 | 70·11 | 41·54 | 64·81 | 61 | 104·31 | 61·80 | 96·42 |
| 41·5 | 70·97 | 42·04 | 65·60 | 61·5 | 105·17 | 62·31 | 97·21 |
| 42 | 71·82 | 42·55 | 66·39 | 62 | 106·02 | 62·82 | 98·00 |
| 42·5 | 72·68 | 43·06 | 67·18 | 62·5 | 106·88 | 63·32 | 98·79 |
| 43 | 73·53 | 43·57 | 67·97 | 63 | 107·73 | 63·83 | 99·58 |
| 43·5 | 74·39 | 44·07 | 68·76 | 63·5 | 108·59 | 64·33 | 100·37 |
| 44 | 75·24 | 44·58 | 69·55 | 64 | 109·44 | 64·84 | 101·16 |
| 44·5 | 76·10 | 45·08 | 70·34 | 64·5 | 110·30 | 65·35 | 101·95 |
| 45 | 76·95 | 45·69 | 71·13 | 65 | 111·15 | 65·85 | 102·74 |
| 45·5 | 77·81 | 46·10 | 71·92 | 65·5 | 112·01 | 66·36 | 103·53 |
| 46 | 78·66 | 46·60 | 72·71 | 66 | 112·86 | 66·87 | 104·32 |
| 46·5 | 79·52 | 47·11 | 73·50 | 66·5 | 113·72 | 67·37 | 105·11 |
| 47 | 80·37 | 47·62 | 74·29 | 67 | 114·57 | 67·88 | 105·90 |
| 47·5 | 81·23 | 48·12 | 75·08 | 67·5 | 115·43 | 68·39 | 106·69 |
| 48 | 82·08 | 48·63 | 75·87 | 68 | 116·28 | 68·89 | 107·48 |
| 48·5 | 82·94 | 49·14 | 76·66 | 68·5 | 117·14 | 69·40 | 108·27 |
| 49 | 83·79 | 49·64 | 77·45 | 69 | 117·99 | 69·91 | 109·06 |
| 49·5 | 84·65 | 50·15 | 78·24 | 69·5 | 118·85 | 70·41 | 109·85 |
| 50 | 85·50 | 50·66 | 79·03 | 70 | 119·70 | 70·92 | 110·64 |
| 50·5 | 86·36 | 51·16 | 79·82 | 70·5 | 120·56 | 71·43 | 111·43 |
| 51 | 87·21 | 51·67 | 80·61 | 71 | 121·41 | 71·93 | 112·23 |
| 51·5 | 88·07 | 52·18 | 81·40 | 71·5 | 122·27 | 72·44 | 113·02 |
| 52 | 88·92 | 52·68 | 82·19 | 72 | 123·12 | 72·95 | 113·81 |
| 52·5 | 89·78 | 53·19 | 82·98 | 72·5 | 123·98 | 73·45 | 114·60 |
| 53 | 90·63 | 53·70 | 83·77 | 73 | 124·83 | 73·96 | 115·39 |
| 53·5 | 91·49 | 54·20 | 84·56 | 73·5 | 125·69 | 74·47 | 116·18 |
| 54 | 92·34 | 54·71 | 85·35 | 74 | 126·54 | 74·97 | 116·97 |
| 54·5 | 93·20 | 55·22 | 86·14 | 74·5 | 127·40 | 75·48 | 117·76 |
| 55 | 94·05 | 55·72 | 86·93 | 75 | 128·25 | 75·99 | 118·55 |
| 55·5 | 94·91 | 56·23 | 87·72 | 75·5 | 129·11 | 76·49 | 119·34 |
| 56 | 95·76 | 56·74 | 88·52 | 76 | 129·96 | 77·00 | 120·13 |
| 56·5 | 96·62 | 57·24 | 89·31 | 76·5 | 130·82 | 77·51 | 120·92 |
| 57 | 97·48 | 57·75 | 90·10 | 77 | 131·67 | 78·01 | 121·71 |
| 57·5 | 98·33 | 58·26 | 90·89 | 77·5 | 132·53 | 78·52 | 122·50 |
| 58 | 99·18 | 58·76 | 91·68 | | | | |
| 58·5 | 100·04 | 59·72 | 92·47 | | | | |
| 59 | 100·89 | 59·77 | 93·26 | | | | |
| 59·5 | 101·75 | 60·28 | 94·05 | | | | |
| 60 | 102·60 | 60·79 | 94·84 | | | | |

**SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM
CARBONATE AT 15° C.**

| Specific gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. by weight. | | 1 cubic metre contains kilog. | |
|-------------------|-------------------|----------------|-----------------------------------|--|-----------------------------------|--|
| | | | Na ₂ CO ₃ . | Na ₂ CO ₃ , 10 aq. | Na ₂ CO ₃ . | Na ₂ CO ₃ , 10 aq. |
| 1·000 | 0 | 0 | 0·00 | 0·00 | 0·00 | 0·00 |
| 1·005 | 1 | 0·7 | 0·45 | 1·21 | 4·52 | 12·16 |
| 1·010 | 2 | 1·4 | 0·91 | 2·46 | 9·19 | 24·85 |
| 1·015 | 3 | 2·1 | 1·39 | 3·75 | 14·11 | 38·06 |
| 1·020 | 4 | 2·7 | 1·90 | 5·13 | 19·38 | 52·33 |
| 1·025 | 5 | 3·4 | 2·35 | 6·34 | 24·09 | 64·99 |
| 1·030 | 6 | 4·1 | 2·82 | 7·61 | 29·05 | 78·38 |
| 1·035 | 7 | 4·7 | 3·27 | 8·82 | 33·84 | 91·29 |
| 1·040 | 8 | 5·4 | 3·74 | 10·09 | 38·90 | 104·94 |
| 1·045 | 9 | 6·0 | 4·21 | 11·36 | 43·99 | 118·71 |
| 1·050 | 10 | 6·7 | 4·70 | 12·68 | 49·35 | 133·14 |
| 1·055 | 11 | 7·4 | 5·17 | 13·95 | 54·54 | 147·17 |
| 1·060 | 12 | 8·0 | 5·65 | 15·24 | 59·89 | 161·54 |
| 1·065 | 13 | 8·7 | 6·15 | 16·59 | 65·50 | 176·68 |
| 1·070 | 14 | 9·4 | 6·63 | 17·89 | 70·94 | 191·42 |
| 1·075 | 15 | 10·0 | 7·08 | 19·10 | 76·11 | 205·33 |
| 1·080 | 16 | 10·6 | 7·56 | 20·40 | 81·65 | 220·32 |
| 1·085 | 17 | 11·2 | 8·03 | 21·67 | 87·13 | 235·12 |
| 1·090 | 18 | 11·9 | 8·48 | 22·88 | 92·43 | 249·39 |
| 1·095 | 19 | 12·4 | 8·90 | 24·01 | 97·46 | 262·91 |
| 1·100 | 20 | 13·0 | 9·31 | 25·12 | 102·41 | 276·32 |
| 1·105 | 21 | 13·6 | 9·80 | 26·44 | 108·29 | 292·16 |
| 1·110 | 22 | 14·2 | 10·27 | 27·71 | 114·00 | 307·58 |
| 1·115 | 23 | 14·9 | 10·75 | 29·00 | 119·86 | 323·35 |
| 1·120 | 24 | 15·4 | 11·22 | 30·27 | 125·66 | 339·02 |
| 1·125 | 25 | 16·0 | 11·67 | 31·49 | 131·29 | 354·26 |
| 1·130 | 26 | 16·5 | 12·17 | 32·83 | 137·52 | 370·98 |
| 1·135 | 27 | 17·0 | 12·64 | 34·10 | 143·46 | 387·04 |
| 1·140 | 28 | 17·7 | 13·08 | 35·29 | 149·11 | 402·31 |
| 1·145 | 29 | 18·3 | 13·50 | 36·42 | 154·58 | 417·01 |
| 1·150 | 30 | 18·8 | 13·94 | 37·61 | 160·31 | 432·52 |
| 1·155 | 31 | 19·3 | 14·34 | 38·69 | 165·63 | 446·87 |

**SPECIFIC GRAVITIES OF CONCENTRATED SOLUTIONS
OF SODIUM CARBONATE AT 30° C.***

| Specific gravity at 30°. | Degrees Twaddell. | Degrees Baumé. | Per cent. by weight. | | 1 cubic metre contains kilog. | |
|--------------------------|-------------------|----------------|-----------------------------------|--|-----------------------------------|--|
| | | | Na ₂ CO ₃ . | Na ₂ CO ₃ , 10 aq. | Na ₂ CO ₃ . | Na ₂ CO ₃ , 10 aq. |
| 1·310 | 62 | 34·2 | 28·08 | 75·76 | 367·85 | 992·46 |
| 1·305 | 61 | 33·7 | 27·66 | 74·63 | 360·96 | 973·92 |
| 1·300 | 60 | 33·3 | 27·25 | 73·52 | 354·25 | 955·76 |
| 1·295 | 59 | 32·8 | 26·84 | 72·41 | 347·58 | 937·71 |
| 1·290 | 58 | 32·4 | 26·42 | 71·28 | 340·82 | 919·51 |
| 1·285 | 57 | 32·0 | 26·00 | 70·15 | 334·10 | 901·43 |
| 1·280 | 56 | 31·5 | 25·60 | 69·07 | 327·68 | 884·10 |
| 1·275 | 55 | 31·1 | 25·18 | 67·94 | 321·05 | 866·24 |
| 1·270 | 54 | 30·6 | 24·74 | 66·75 | 314·20 | 847·73 |
| 1·265 | 53 | 30·2 | 24·28 | 65·51 | 307·14 | 828·70 |
| 1·260 | 52 | 29·7 | 23·85 | 64·35 | 300·51 | 810·81 |
| 1·255 | 51 | 29·3 | 23·43 | 63·21 | 294·05 | 793·29 |
| 1·250 | 50 | 28·8 | 23·03 | 62·14 | 287·88 | 776·75 |
| 1·245 | 49 | 28·4 | 22·63 | 61·06 | 281·74 | 760·20 |
| 1·240 | 48 | 27·9 | 22·22 | 59·95 | 275·53 | 743·38 |
| 1·235 | 47 | 27·4 | 21·80 | 58·82 | 269·23 | 726·43 |
| 1·230 | 46 | 26·9 | 21·37 | 57·66 | 262·85 | 709·22 |
| 1·225 | 45 | 26·4 | 20·96 | 56·55 | 256·76 | 692·73 |
| 1·220 | 44 | 26·0 | 20·55 | 55·44 | 250·71 | 676·37 |
| 1·215 | 43 | 25·5 | 20·12 | 54·28 | 244·46 | 659·50 |
| 1·210 | 42 | 25·0 | 19·67 | 53·07 | 238·01 | 642·15 |
| 1·205 | 41 | 24·5 | 19·26 | 51·96 | 232·08 | 626·12 |
| 1·200 | 40 | 24·0 | 18·83 | 50·80 | 225·96 | 609·60 |
| 1·195 | 39 | 23·5 | 18·42 | 49·70 | 220·42 | 594·22 |
| 1·190 | 38 | 23·0 | 18·00 | 48·56 | 214·20 | 577·84 |
| 1·185 | 37 | 22·5 | 17·55 | 47·35 | 207·97 | 561·10 |
| 1·180 | 36 | 22·0 | 17·09 | 46·11 | 201·66 | 544·10 |
| 1·175 | 35 | 21·4 | 16·62 | 44·84 | 195·29 | 526·87 |
| 1·170 | 34 | 20·9 | 16·16 | 43·60 | 189·07 | 510·12 |
| 1·165 | 33 | 20·3 | 15·70 | 42·36 | 182·91 | 493·49 |
| 1·160 | 32 | 19·8 | 15·25 | 41·14 | 176·90 | 477·22 |
| 1·155 | 31 | 19·3 | 14·84 | 40·04 | 171·40 | 462·46 |
| 1·150 | 30 | 18·8 | 14·42 | 38·91 | 165·83 | 447·47 |
| 1·145 | 29 | 18·3 | 14·02 | 37·83 | 160·53 | 433·15 |
| 1·140 | 28 | 17·7 | 13·61 | 36·72 | 155·15 | 418·61 |

* This temperature has been specially chosen, because the higher concentrations of sodium carbonate cannot exist in solution at lower temperatures.

INFLUENCE OF TEMPERATURE ON THE SPECIFIC

| 0° C. | 5°. | 10°. | 15°. | 20°. | 25° | 30°. | 35°. | 40° | 45° | 50°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| .. | ... | ... | ... | ... | ... | 1·285 | 1·282 | 1·279 | 1·276 | 1·273 |
| ... | ... | ... | ... | ... | ... | 1·274 | 1·271 | 1·267 | 1·265 | 1·262 |
| ... | ... | ... | ... | ... | ... | 1·263 | 1·260 | 1·257 | 1·254 | 1·251 |
| ... | ... | ... | ... | ... | ... | 1·252 | 1·250 | 1·247 | 1·244 | 1·240 |
| ... | .. | ... | ... | ... | ... | 1·241 | 1·239 | 1·236 | 1·233 | 1·230 |
| ... | ... | ... | 1·210 | 1·238 | 1·236 | 1·234 | 1·232 | 1·230 | 1·227 | 1·224 |
| ... | ... | ... | 1·230 | 1·228 | 1·225 | 1·223 | 1·221 | 1·219 | 1·216 | 1·213 |
| ... | ... | ... | 1·220 | 1·218 | 1·215 | 1·213 | 1·210 | 1·208 | 1·205 | 1·201 |
| ... | ... | ... | 1·210 | 1·208 | 1·206 | 1·204 | 1·201 | 1·199 | 1·196 | 1·192 |
| ... | ... | ... | 1·200 | 1·198 | 1·196 | 1·194 | 1·192 | 1·189 | 1·186 | 1·183 |
| 1·198 | 1·195 | 1·193 | 1·190 | 1·188 | 1·186 | 1·184 | 1·182 | 1·179 | 1·176 | 1·173 |
| 1·188 | 1·185 | 1·183 | 1·180 | 1·178 | 1·176 | 1·174 | 1·172 | 1·169 | 1·166 | 1·163 |
| 1·177 | 1·174 | 1·172 | 1·170 | 1·168 | 1·166 | 1·164 | 1·162 | 1·160 | 1·157 | 1·154 |
| 1·166 | 1·164 | 1·162 | 1·160 | 1·158 | 1·156 | 1·154 | 1·152 | 1·150 | 1·148 | 1·145 |
| 1·156 | 1·154 | 1·152 | 1·150 | 1·148 | 1·146 | 1·144 | 1·142 | 1·139 | 1·136 | 1·134 |
| 1·146 | 1·144 | 1·142 | 1·140 | 1·138 | 1·136 | 1·134 | 1·132 | 1·129 | 1·126 | 1·123 |
| 1·136 | 1·134 | 1·132 | 1·130 | 1·128 | 1·126 | 1·124 | 1·122 | 1·120 | 1·117 | 1·114 |
| 1·126 | 1·124 | 1·122 | 1·120 | 1·118 | 1·116 | 1·114 | 1·112 | 1·110 | 1·107 | 1·104 |
| 1·116 | 1·114 | 1·112 | 1·110 | 1·108 | 1·106 | 1·104 | 1·102 | 1·100 | 1·098 | 1·095 |
| 1·106 | 1·104 | 1·102 | 1·100 | 1·098 | 1·096 | 1·094 | 1·092 | 1·090 | 1·088 | 1·085 |
| 1·096 | 1·094 | 1·092 | 1·090 | 1·088 | 1·086 | 1·084 | 1·082 | 1·080 | 1·078 | 1·075 |
| 1·086 | 1·084 | 1·082 | 1·080 | 1·078 | 1·076 | 1·074 | 1·072 | 1·070 | 1·068 | 1·065 |
| 1·075 | 1·073 | 1·071 | 1·070 | 1·069 | 1·067 | 1·065 | 1·063 | 1·061 | 1·059 | 1·056 |
| 1·064 | 1·063 | 1·061 | 1·060 | 1·059 | 1·057 | 1·056 | 1·054 | 1·052 | 1·050 | 1·047 |
| 1·053 | 1·052 | 1·051 | 1·050 | 1·049 | 1·048 | 1·046 | 1·044 | 1·042 | 1·040 | 1·037 |
| 1·043 | 1·042 | 1·041 | 1·040 | 1·039 | 1·038 | 1·036 | 1·034 | 1·032 | 1·030 | 1·027 |
| 1·033 | 1·032 | 1·031 | 1·030 | 1·029 | 1·028 | 1·026 | 1·024 | 1·022 | 1·020 | 1·017 |
| 1·023 | 1·022 | 1·021 | 1·020 | 1·019 | 1·018 | 1·016 | 1·014 | 1·012 | 1·010 | 1·007 |
| 1·013 | 1·012 | 1·011 | 1·010 | 1·009 | 1·008 | 1·006 | 1·004 | 1·002 | 1·000 | 0·997 |

ANALYSIS OF COMMERCIAL SODA ASH 197

GRAVITIES OF SOLUTIONS OF SODIUM CARBONATE.

| 55°. | 60°. | 65°. | 70°. | 75°. | 80°. | 85°. | 90°. | 95°. | 100°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·270 | 1·267 | 1·264 | 1·260 | 1·256 | 1·252 | 1·247 | 1·243 | 1·238 | 1·234 |
| 1·259 | 1·256 | 1·253 | 1·249 | 1·244 | 1·240 | 1·236 | 1·232 | 1·228 | 1·224 |
| 1·248 | 1·245 | 1·241 | 1·237 | 1·233 | 1·229 | 1·226 | 1·222 | 1·218 | 1·215 |
| 1·237 | 1·234 | 1·230 | 1·227 | 1·224 | 1·220 | 1·217 | 1·213 | 1·210 | 1·206 |
| 1·226 | 1·223 | 1·220 | 1·216 | 1·213 | 1·210 | 1·207 | 1·204 | 1·200 | 1·197 |
| 1·220 | 1·217 | 1·213 | 1·210 | 1·206 | 1·203 | 1·199 | 1·195 | 1·191 | 1·188 |
| 1·209 | 1·206 | 1·202 | 1·199 | 1·195 | 1·192 | 1·188 | 1·184 | 1·181 | 1·178 |
| 1·198 | 1·194 | 1·191 | 1·188 | 1·184 | 1·181 | 1·178 | 1·174 | 1·171 | 1·168 |
| 1·189 | 1·185 | 1·182 | 1·178 | 1·175 | 1·172 | 1·168 | 1·165 | 1·162 | 1·159 |
| 1·179 | 1·176 | 1·172 | 1·168 | 1·165 | 1·162 | 1·158 | 1·155 | 1·152 | 1·149 |
| 1·169 | 1·166 | 1·163 | 1·159 | 1·156 | 1·153 | 1·149 | 1·146 | 1·143 | 1·140 |
| 1·160 | 1·156 | 1·153 | 1·150 | 1·147 | 1·144 | 1·140 | 1·137 | 1·134 | 1·131 |
| 1·151 | 1·147 | 1·144 | 1·141 | 1·138 | 1·135 | 1·131 | 1·128 | 1·125 | 1·122 |
| 1·142 | 1·139 | 1·136 | 1·133 | 1·130 | 1·126 | 1·123 | 1·120 | 1·117 | 1·114 |
| 1·131 | 1·128 | 1·125 | 1·122 | 1·119 | 1·116 | 1·113 | 1·110 | 1·107 | 1·104 |
| 1·120 | 1·118 | 1·115 | 1·112 | 1·109 | 1·106 | 1·103 | 1·100 | 1·097 | 1·094 |
| 1·111 | 1·108 | 1·105 | 1·102 | 1·099 | 1·096 | 1·093 | 1·090 | 1·087 | 1·084 |
| 1·101 | 1·098 | 1·095 | 1·092 | 1·089 | 1·086 | 1·083 | 1·080 | 1·077 | 1·074 |
| 1·092 | 1·089 | 1·086 | 1·083 | 1·080 | 1·077 | 1·074 | 1·071 | 1·068 | 1·065 |
| 1·082 | 1·079 | 1·076 | 1·073 | 1·070 | 1·067 | 1·064 | 1·061 | 1·058 | 1·055 |
| 1·072 | 1·070 | 1·067 | 1·064 | 1·061 | 1·058 | 1·055 | 1·052 | 1·049 | 1·046 |
| 1·062 | 1·060 | 1·057 | 1·054 | 1·052 | 1·049 | 1·046 | 1·043 | 1·040 | 1·038 |
| 1·053 | 1·051 | 1·048 | 1·045 | 1·043 | 1·040 | 1·037 | 1·034 | 1·032 | 1·029 |
| 1·044 | 1·041 | 1·038 | 1·036 | 1·032 | 1·030 | 1·028 | 1·025 | 1·023 | 1·020 |
| 1·034 | 1·032 | 1·029 | 1·027 | 1·024 | 1·021 | 1·019 | 1·016 | 1·014 | 1·011 |
| 1·024 | 1·022 | 1·019 | 1·017 | 1·015 | 1·012 | 1·010 | 1·007 | 1·005 | 1·003 |
| 1·014 | 1·012 | 1·009 | 1·007 | 1·005 | 1·002 | 1·000 | 0·997 | 0·995 | 0·993 |
| 1·004 | 1·002 | 0·999 | 0·997 | 0·995 | 0·992 | 0·990 | 0·987 | 0·985 | 0·983 |
| 0·994 | 0·992 | 0·989 | 0·987 | 0·985 | 0·982 | 0·980 | 0·977 | 0·975 | 0·973 |

Sulphur Recovery (Chance Process).

1. *Estimation of Sulphur as Sulphide in Vat Waste.*—The apparatus consists of a small flask fitted with a stopcock funnel and outlet tube connected with two Mohr's potash bulbs, the first one being empty, the second containing a strong solution of caustic potash. (In lieu of Mohr's bulbs a tube of the shape shown in Fig. 10, p. 144, can be employed with great advantage.) It is preferable to connect the last potash bulb to an aspirator or Bunsen pump, to produce a slight vacuum. About 2 g. of vat waste is put into the flask, and a sufficient quantity of water is added. Then hydrochloric acid, diluted with its volume of water, is run in from the funnel gradually. After the decomposition has ceased, the solution is boiled, until the whole of the gases are displaced by steam, most of the steam condensing in the first empty potash bulbs. When enough steam has been produced to bring the first bulb of the second set, filled with potash solution, up to boiling, the tap of the funnel is opened, and the apparatus allowed to cool down. The potash solution is then transferred to a $\frac{1}{4}$ or $\frac{1}{2}$ litre flask, made up to the mark, an aliquot part taken, diluted with a large quantity of previously boiled water (free from air), neutralised with acetic acid, and titrated with decinormal iodine, each c.c. of which indicates 0.001604 g. S.

2. *Sulphur as Sulphide in Carbonated Mud.*—About 6 g. is taken for analysis; otherwise the test is conducted just like the preceding one.

3. *Sulphide-sulphur + Carbonic Acid in Vat Waste.*—This test (which is only exceptionally made) is carried out in a small flask, fitted with stopcock funnel, connected with a U-tube containing sodium sulphate to absorb any traces of HCl passing over, and a sufficient number of chloride of calcium tubes to thoroughly dry the gases. To the last of these are connected two weighed potash bulbs containing a strong solution of caustic potash, followed by weighed CaCl_2 tubes. The whole apparatus being connected, 2 g. of vat waste is put into the flask, and some water added. A current of nitrogen is then passed through the apparatus to displace the air. [Nitrogen from a cylinder may be passed through a solution of potassium hydroxide to remove any trace of carbon dioxide.] The vat waste is then decomposed by hydrochloric acid, and the contents of the flask are boiled. Afterwards a current of nitrogen is passed through the apparatus for a considerable time to displace the H_2S and CO_2 in the flask and drying tubes. The potash bulbs and the last drying tubes are reweighed, the increase showing the amount of $\text{H}_2\text{S} + \text{CO}_2$ in the vat waste employed. The potash solution is then transferred to a

measuring flask, and the H_2S estimated as described in 1. Deducting the amount from the increase of weight of the absorbing apparatus, we find the amount of CO_2 present.

4. *Sulphur as Sulphide in Solutions of Calcium or Sodium Sulphhydrates and Sulphides.*—10 c.c. is diluted to 250, and of this liquid a convenient portion is taken out, largely diluted with air-free water, acidulated with acetic acid, and titrated with iodine, as in test 1. If thiosulphates are present, they are estimated as in 5, and deducted. If polysulphides are present, the sulphur which would be precipitated by an acid is not estimated by this method, but only that which would be liberated as H_2S by an acid.

5. *Soda, Lime, and Thiosulphate in Sulphur Liquors.*—In one sample of the liquor, say 5 c.c., estimate the total alkalinity, i.e. $\text{Na}_2\text{O} + \text{CaO}$, by standard hydrochloric acid and methyl orange. Take another sample, say 50 c.c., pass pure CO_2 in till lead paper shows the absence of all sulphides, boil to decompose calcium bicarbonate, dilute with water to 500 c.c., allow the precipitate to settle, take 50 c.c. of the clear liquor and titrate again, the alkalinity this time being due to Na_2O only. CaO is found from the difference between the two titrations.

Another sample of the carbonated liquor is titrated with decinormal iodine for thiosulphate. Each c.c. of iodine solution indicates 0.006414 g. S. as thiosulphate.

6. *Lime-kiln Gases.*— CO_2 is estimated by an Orsat apparatus, or a Honigmann burette, or any other similar apparatus. When using an Orsat apparatus, the test for oxygen can be made as on p. 119.

7. Gas from Gas-holder.

(a) *Hydrogen Sulphide + Carbon Dioxide* are estimated by an Orsat apparatus or a Honigmann burette, etc.

(b) *Hydrogen Sulphide only.*—A wide-mouthed bottle of known capacity, holding about 500 c.c., is fitted with a rubber cork and two tubes, one nearly reaching to the bottom, the other ending just below the cork, both of them with stopcocks outside. Gas is passed through for some time, till it has entirely displaced the air in the bottle. Then 20 or 25 c.c. of standard potash solution is run in from a pipette, through one of the stopcocks, the bottle is well shaken until the whole of the H_2S and CO_2 are absorbed, the contents of the bottle are poured into a measuring flask, the bottle is rinsed out completely, and the total liquid made up to the mark.

An aliquot portion is taken out, largely diluted with previously boiled water, acidified with acetic acid, and the H_2S

estimated by iodine. In this case a solution of iodine is employed containing 11.463 g. I per litre, each c.c. of which indicates 1 c.c. of gaseous H_2S at 0°C . and 760 mm. pressure. For somewhat exact estimations, the temperature, pressure, and vapour tension have to be taken into account; but it is unnecessary to observe the thermometer and barometer, and to make any complicated calculations, if a Lunge's gas-volumeter be used (p. 167). In this case the level-tube, C, of the instrument is placed so that the mercury stands at the same height in C as in the reduction tube B; the height of mercury in the latter is read off, which gives the volume occupied by 100 c.c. of dry air of 0° and 760 mm. under the prevailing atmospheric conditions; the number of c.c. of iodine solution, multiplied by 100, is divided by this figure, and thus the correction of the normal volume effected.

8. *Erit Gases from the Claus Kilns.*—These contain SO_2 and H_2S . Both these gases, on being passed through iodine solution, produce 2HI for each atom of S; but whilst H_2S does not further increase the acidity of the solution, SO_2 produces its equivalent of H_2SO_4 . Hence SO_2 and H_2S are measured together by the amount of iodine converted into HI , and SO_2 by the acidity present after the HI has been saturated with caustic soda. Since the current of gases carries away some iodine from the decinormal solution, the gases must be passed through caustic soda, or, better, through sodium thiosulphate, to intercept this iodine. The manipulation is hence as follows: Aspirate one or more litres of the gases through 50 c.c. of decinormal iodine solution, contained in a bulb apparatus (Fig. 10, p. 144), or other efficient absorbing-tubes, followed by another apparatus containing 50 c.c. of decinormal thiosulphate solution. Empty the contents of both apparatus into a beaker, and titrate with decinormal iodine and starch solution, till a blue colour appears. The number of c.c. of iodine solution used, if multiplied by 0.001604 g. indicates the total sulphur present as SO_2 and H_2S . Now add a drop of thiosulphate solution to discharge the blue colour, then a drop of methyl orange, and decinormal caustic soda from a burette, till the pink colour of the liquid is discharged. The number of c.c. of caustic soda used, less those of iodine used in the preceding test, multiplied by 0.001604, indicates the sulphur present as SO_2 .

VIII. MANUFACTURE OF SODA BY THE AMMONIA PROCESS.

A.—Raw Materials.

1. *Rock Salt*, compare p. 174.
2. *Brine*.—The following determinations are made :—
 - (a) *Specific Gravity*, by the hydrometer.
 - (b) *Chlorine*, expressed as NaCl. Dilute 10 c.c. to 1 litre, and titrate 10 c.c. of the diluted solution as on p. 174.
 - (c) *Sulphates*.—Dilute 50 c.c. brine to 150 or 200 c.c., add a little hydrochloric acid, and precipitate with barium chloride as on p. 134.
 - (d) *Ferric Oxide and Alumina*.—To 500 c.c. brine add a little nitric acid, heat to 80°, precipitate by an excess of ammonia, digest for half an hour at 80°, filter, and wash well. As a check, redissolve the precipitate in hydrochloric acid and reprecipitate it by ammonia.In the filtrate *lime* and *magnesia* may be estimated as on pp. 174 and 175.
- (c) *Bicarbonates of Iron, Lime, and Magnesia*.—Destroy the bicarbonates as such by prolonged boiling of 500 c.c., replace the water driven off, filter the precipitate formed, wash it, dissolve it in hydrochloric acid, and in the solution estimate the iron by precipitation with NH_3 , and lime and magnesia in the ordinary way.
3. *Concentrated Gas-Liquor or Sulphate of Ammonia*, cf. Chapter XIII., pp. 233 and 234.
4. *Limestone*, cf. p. 183.
5. *Quicklime*, cf. p. 184.
6. *Coals or Coke*, cf. p. 117.

B.—Tests made during the Process of Manufacture.

1. *Ammoniacal Brine* from the receivers.
 - (a) *Sodium Chloride*.—Acidulate with nitric acid and estimate the NaCl by AgNO_3 gravimetrically, or volumetrically in the neutral or faintly alkaline solution as on p. 174.
 - (b) *Ammonia, free and combined*.—Dilute 10 c.c. to 100 c.c. and boil in a distilling flask until all the free ammonia and ammonium carbonate has been expelled; absorb this in a measured volume of normal sulphuric acid, and titrate back. To

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the solution remaining in the flask add caustic soda solution, distil again, and absorb this "combined" ammonia also in sulphuric acid. *Cf.* Chapter XIII., p. 233.

2. *Carbonators*.—Free and combined NH_3 are estimated as in No. 1 (b).

3. *Mother Liquor*.—Estimate :—

(a) NH_3 , free and combined, as above.

(b) Undecomposed NaCl , by evaporating 10 c.c. in a platinum dish, heating until all NH_4Cl is expelled, and weighing.

4. *Crude Bicarbonate*.—Estimate :—

(a) *The Alkalimetric Degree*, as on p. 190.

(b) CO_2 as on p. 209.

(c) Moisture, by igniting and allowing for the CO_2 present as bicarbonate and found in (b).

5. *Distillation of Ammonia* :—

(a) NH_3 , free and combined, in the mother liquor, as in No. 1 (b).

(b) Milk of lime, as on p. 184.

(c) Excess of lime in the stills. Boil 100 c.c. until all NH_3 has been expelled, add a little ammonium sulphate, and boil again. The NH_3 now set free, which corresponds to the excess of lime, is absorbed in standard sulphuric acid and titrated.

6. *Lime-kiln Gases*.—Estimate the CO_2 as on p. 119.

C.—Commercial Products.

1. *Soda Ash*, as on p. 190.

2. *Commercial Bicarbonate* is tested like the crude, No. 1, or very accurately by heating in an air-bath to 270° and receiving the gas in a Lunge's gas-volumeter, p. 167 (compare Lunge, *Z. angew. Chem.*, 1897, p. 522).

IX. CAUSTIC SODA.

A.—Caustic Liquor.

(a) Test for total alkali by titration with standard acid, using methyl orange as indicator. If carbonate is present, it can be determined as described on p. 209.

**(b) SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM
HYDROXIDE AT 15° C.**

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. Na ₂ O. | Per cent. NaOH. | 1 cb.m. contains kg. | |
|-------------------|-------------------|----------------|------------------------------|-----------------|----------------------|--------|
| | | | | | Na ₂ O. | NaOH. |
| 1·000 | 0 | 0 | 0 | 0·00 | 0 | 0 |
| 1·005 | 1 | 0·7 | 0·33 | 0·43 | 3·31 | 4·32 |
| 1·010 | 2 | 1·4 | 0·67 | 0·86 | 6·77 | 8·69 |
| 1·015 | 3 | 2·1 | 0·99 | 1·28 | 10·05 | 12·99 |
| 1·020 | 4 | 2·7 | 1·31 | 1·69 | 13·36 | 17·24 |
| 1·025 | 5 | 3·4 | 1·65 | 2·13 | 16·91 | 21·83 |
| 1·030 | 6 | 4·1 | 2·02 | 2·60 | 20·81 | 26·78 |
| 1·035 | 7 | 4·7 | 2·37 | 3·06 | 24·53 | 31·67 |
| 1·040 | 8 | 5·4 | 2·71 | 3·50 | 28·18 | 36·40 |
| 1·045 | 9 | 6·0 | 3·02 | 3·90 | 31·56 | 40·76 |
| 1·050 | 10 | 6·7 | 3·36 | 4·34 | 35·28 | 45·57 |
| 1·055 | 11 | 7·4 | 3·69 | 4·76 | 38·93 | 50·22 |
| 1·060 | 12 | 8·0 | 4·03 | 5·20 | 42·72 | 55·12 |
| 1·065 | 13 | 8·7 | 4·39 | 5·67 | 46·75 | 60·39 |
| 1·070 | 14 | 9·4 | 4·75 | 6·13 | 50·83 | 65·59 |
| 1·075 | 15 | 10·0 | 5·10 | 6·58 | 54·83 | 70·74 |
| 1·080 | 16 | 10·6 | 5·46 | 7·05 | 58·97 | 76·14 |
| 1·085 | 17 | 11·2 | 5·81 | 7·50 | 63·04 | 81·38 |
| 1·090 | 18 | 11·9 | 6·16 | 7·95 | 67·14 | 86·66 |
| 1·095 | 19 | 12·4 | 6·50 | 8·39 | 71·18 | 91·87 |
| 1·100 | 20 | 13·0 | 6·81 | 8·78 | 74·91 | 96·58 |
| 1·105 | 21 | 13·6 | 7·15 | 9·23 | 79·01 | 101·99 |
| 1·110 | 22 | 14·2 | 7·50 | 9·67 | 83·25 | 107·34 |
| 1·115 | 23 | 14·9 | 7·84 | 10·12 | 87·42 | 112·84 |
| 1·120 | 24 | 15·4 | 8·18 | 10·56 | 91·62 | 118·27 |
| 1·125 | 25 | 16·0 | 8·57 | 11·06 | 96·41 | 124·43 |
| 1·130 | 26 | 16·5 | 8·95 | 11·55 | 101·14 | 130·52 |
| 1·135 | 27 | 17·0 | 9·32 | 12·02 | 105·78 | 136·43 |
| 1·140 | 28 | 17·7 | 9·68 | 12·49 | 110·35 | 142·39 |
| 1·145 | 29 | 18·3 | 10·03 | 12·94 | 114·84 | 148·16 |
| 1·150 | 30 | 18·8 | 10·34 | 13·34 | 118·91 | 153·41 |
| 1·155 | 31 | 19·3 | 10·67 | 13·76 | 123·24 | 158·93 |
| 1·160 | 32 | 19·8 | 11·00 | 14·19 | 127·60 | 164·60 |
| 1·165 | 33 | 20·3 | 11·33 | 14·62 | 131·99 | 170·32 |
| 1·170 | 34 | 20·9 | 11·67 | 15·06 | 136·54 | 176·20 |
| 1·175 | 35 | 21·4 | 12·04 | 15·53 | 141·47 | 182·48 |
| 1·180 | 36 | 22·0 | 12·40 | 16·00 | 146·32 | 188·80 |
| 1·185 | 37 | 22·5 | 12·75 | 16·45 | 151·09 | 194·93 |
| 1·190 | 38 | 23·0 | 13·11 | 16·91 | 156·01 | 201·23 |
| 1·195 | 39 | 23·5 | 13·46 | 17·36 | 160·85 | 207·45 |
| 1·200 | 40 | 24·0 | 13·80 | 17·81 | 165·60 | 213·72 |
| 1·205 | 41 | 24·5 | 14·15 | 18·26 | 170·51 | 220·03 |

(b) SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM HYDROXIDE AT 15° C.—*Continued.*

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. Na ₂ O. | Per cent. NaOH. | 1 cb.m. contains kg. | |
|-------------------|-------------------|----------------|------------------------------|-----------------|----------------------|--------|
| | | | | | Na ₂ O. | NaOH. |
| 1.210 | 42 | 25.0 | 14.50 | 18.71 | 175.45 | 226.39 |
| 1.215 | 43 | 25.5 | 14.87 | 19.18 | 180.67 | 233.04 |
| 1.220 | 44 | 26.0 | 15.23 | 19.65 | 185.81 | 239.73 |
| 1.225 | 45 | 26.4 | 15.59 | 20.12 | 190.98 | 246.47 |
| 1.230 | 46 | 26.9 | 15.97 | 20.60 | 196.43 | 253.38 |
| 1.235 | 47 | 27.4 | 16.30 | 21.03 | 201.31 | 259.72 |
| 1.240 | 48 | 27.9 | 16.64 | 21.47 | 206.34 | 266.23 |
| 1.245 | 49 | 28.4 | 16.97 | 21.90 | 211.28 | 272.66 |
| 1.250 | 50 | 28.8 | 17.31 | 22.33 | 216.38 | 279.13 |
| 1.255 | 51 | 29.3 | 17.65 | 22.77 | 221.51 | 285.76 |
| 1.260 | 52 | 29.7 | 18.01 | 23.23 | 226.93 | 292.70 |
| 1.265 | 53 | 30.2 | 18.35 | 23.68 | 232.13 | 299.55 |
| 1.270 | 54 | 30.6 | 18.70 | 24.13 | 237.62 | 306.45 |
| 1.275 | 55 | 31.1 | 19.05 | 24.58 | 242.89 | 313.40 |
| 1.280 | 56 | 31.5 | 19.41 | 25.04 | 248.15 | 320.51 |
| 1.285 | 57 | 32.0 | 19.77 | 25.50 | 254.04 | 327.68 |
| 1.290 | 58 | 32.4 | 20.12 | 25.96 | 259.55 | 334.88 |
| 1.295 | 59 | 32.8 | 20.47 | 26.41 | 265.09 | 342.01 |
| 1.300 | 60 | 33.3 | 20.81 | 26.85 | 270.53 | 349.05 |
| 1.305 | 61 | 33.7 | 21.20 | 27.35 | 276.66 | 356.92 |
| 1.310 | 62 | 34.2 | 21.59 | 27.85 | 282.83 | 364.83 |
| 1.315 | 63 | 34.6 | 21.97 | 28.34 | 288.91 | 372.67 |
| 1.320 | 64 | 35.0 | 22.35 | 28.83 | 295.02 | 380.56 |
| 1.325 | 65 | 35.4 | 22.73 | 29.32 | 301.17 | 388.40 |
| 1.330 | 66 | 35.8 | 23.10 | 29.80 | 307.23 | 396.34 |
| 1.335 | 67 | 36.2 | 23.47 | 30.28 | 313.32 | 404.24 |
| 1.340 | 68 | 36.6 | 23.83 | 30.74 | 319.32 | 411.92 |
| 1.345 | 69 | 37.0 | 24.18 | 31.20 | 325.22 | 419.64 |
| 1.350 | 70 | 37.4 | 24.61 | 31.75 | 332.24 | 428.63 |
| 1.355 | 71 | 37.8 | 25.02 | 32.28 | 339.02 | 437.39 |
| 1.360 | 72 | 38.2 | 25.42 | 32.79 | 345.71 | 445.94 |
| 1.365 | 73 | 38.6 | 25.78 | 33.26 | 351.90 | 454.00 |
| 1.370 | 74 | 39.0 | 26.14 | 33.73 | 358.12 | 462.10 |
| 1.375 | 75 | 39.4 | 26.52 | 34.22 | 364.65 | 470.53 |
| 1.380 | 76 | 39.8 | 26.90 | 34.71 | 371.22 | 479.00 |
| 1.385 | 77 | 40.1 | 27.28 | 35.20 | 377.83 | 487.52 |
| 1.390 | 78 | 40.5 | 27.66 | 35.68 | 384.47 | 495.95 |
| 1.395 | 79 | 40.8 | 28.02 | 36.15 | 390.88 | 504.29 |
| 1.400 | 80 | 41.2 | 28.42 | 36.67 | 397.88 | 513.38 |
| 1.405 | 81 | 41.6 | 28.81 | 37.17 | 404.78 | 522.24 |
| 1.410 | 82 | 42.0 | 29.18 | 37.65 | 411.44 | 530.87 |
| 1.415 | 83 | 42.3 | 29.58 | 38.16 | 418.56 | 539.96 |

**(b) SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM
HYDROXIDE AT 15° C.—Continued.**

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. Na ₂ O. | Per cent. NaOH. | 1 cb.m. contains kg. | |
|-------------------|-------------------|----------------|------------------------------|-----------------|----------------------|--------|
| | | | | | Na ₂ O. | NaOH. |
| 1.420 | 84 | 42.7 | 29.97 | 38.67 | 425.57 | 549.11 |
| 1.425 | 85 | 43.1 | 30.36 | 39.17 | 432.63 | 558.17 |
| 1.430 | 86 | 43.4 | 30.75 | 39.67 | 439.72 | 567.28 |
| 1.435 | 87 | 43.8 | 31.14 | 40.18 | 446.86 | 576.58 |
| 1.440 | 88 | 44.1 | 31.53 | 40.68 | 454.03 | 585.79 |
| 1.445 | 89 | 44.4 | 31.93 | 41.20 | 461.39 | 595.34 |
| 1.450 | 90 | 44.8 | 32.32 | 41.70 | 468.64 | 604.65 |
| 1.455 | 91 | 45.1 | 32.72 | 42.22 | 476.07 | 614.30 |
| 1.460 | 92 | 45.4 | 33.14 | 42.75 | 483.84 | 624.15 |
| 1.465 | 93 | 45.8 | 33.54 | 43.27 | 491.36 | 633.91 |
| 1.470 | 94 | 46.1 | 33.95 | 43.80 | 499.07 | 643.86 |
| 1.475 | 95 | 46.4 | 34.36 | 44.33 | 506.81 | 653.87 |
| 1.480 | 96 | 46.8 | 34.76 | 44.85 | 514.45 | 663.78 |
| 1.485 | 97 | 47.1 | 35.17 | 45.37 | 522.27 | 673.74 |
| 1.490 | 98 | 47.4 | 35.57 | 45.89 | 529.99 | 683.76 |
| 1.495 | 99 | 47.8 | 35.98 | 46.42 | 537.90 | 693.98 |
| 1.500 | 100 | 48.1 | 36.38 | 46.94 | 545.70 | 704.10 |
| 1.505 | 101 | 48.4 | 36.79 | 47.47 | 553.69 | 714.42 |
| 1.510 | 102 | 48.7 | 37.20 | 48.00 | 561.72 | 724.80 |
| 1.515 | 103 | 49.0 | 37.61 | 48.53 | 569.79 | 735.23 |
| 1.520 | 104 | 49.4 | 38.02 | 49.05 | 577.90 | 745.56 |
| 1.525 | 105 | 49.7 | 38.42 | 49.58 | 585.91 | 756.10 |
| 1.530 | 106 | 50.0 | 38.83 | 50.10 | 594.10 | 766.53 |

[(c) INFLUENCE OF TEMPERATURE.

(c) INFLUENCE OF TEMPERATURE ON THE SPECIFIC

| 0° C. | 5°. | 10°. | 15°. | 20°. | 25°. | 30°. | 35°. | 40°. | 45°. | 50°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·867 | 1·864 | 1·862 | 1·860 | 1·357 | 1·355 | 1·858 | 1·850 | 1·848 | 1·845 | 1·842 |
| 1·857 | 1·854 | 1·852 | 1·850 | 1·347 | 1·345 | 1·848 | 1·840 | 1·837 | 1·835 | 1·832 |
| 1·847 | 1·844 | 1·842 | 1·840 | 1·338 | 1·335 | 1·838 | 1·830 | 1·827 | 1·825 | 1·822 |
| 1·838 | 1·835 | 1·832 | 1·830 | 1·328 | 1·325 | 1·828 | 1·820 | 1·817 | 1·815 | 1·812 |
| 1·828 | 1·825 | 1·822 | 1·820 | 1·318 | 1·315 | 1·818 | 1·810 | 1·807 | 1·805 | 1·802 |
| 1·818 | 1·815 | 1·813 | 1·810 | 1·308 | 1·305 | 1·808 | 1·800 | 1·297 | 1·294 | 1·292 |
| 1·808 | 1·805 | 1·803 | 1·800 | 1·297 | 1·294 | 1·292 | 1·289 | 1·287 | 1·284 | 1·282 |
| 1·298 | 1·295 | 1·293 | 1·290 | 1·287 | 1·284 | 1·282 | 1·279 | 1·277 | 1·274 | 1·272 |
| 1·288 | 1·285 | 1·283 | 1·280 | 1·277 | 1·274 | 1·272 | 1·269 | 1·267 | 1·264 | 1·262 |
| 1·278 | 1·275 | 1·273 | 1·270 | 1·267 | 1·265 | 1·262 | 1·260 | 1·258 | 1·255 | 1·252 |
| 1·268 | 1·265 | 1·263 | 1·260 | 1·257 | 1·255 | 1·252 | 1·250 | 1·248 | 1·245 | 1·242 |
| 1·257 | 1·255 | 1·252 | 1·250 | 1·247 | 1·245 | 1·242 | 1·240 | 1·238 | 1·235 | 1·233 |
| 1·247 | 1·245 | 1·242 | 1·240 | 1·237 | 1·235 | 1·232 | 1·230 | 1·228 | 1·225 | 1·223 |
| 1·237 | 1·235 | 1·232 | 1·230 | 1·227 | 1·224 | 1·222 | 1·220 | 1·218 | 1·215 | 1·212 |
| 1·227 | 1·225 | 1·222 | 1·220 | 1·217 | 1·214 | 1·212 | 1·210 | 1·208 | 1·205 | 1·202 |
| 1·217 | 1·215 | 1·212 | 1·210 | 1·207 | 1·204 | 1·203 | 1·200 | 1·198 | 1·196 | 1·192 |
| 1·207 | 1·205 | 1·202 | 1·200 | 1·197 | 1·195 | 1·193 | 1·190 | 1·188 | 1·186 | 1·184 |
| 1·197 | 1·195 | 1·192 | 1·190 | 1·187 | 1·185 | 1·183 | 1·180 | 1·178 | 1·176 | 1·174 |
| 1·187 | 1·185 | 1·182 | 1·180 | 1·177 | 1·175 | 1·173 | 1·170 | 1·168 | 1·166 | 1·164 |
| 1·176 | 1·174 | 1·172 | 1·170 | 1·167 | 1·165 | 1·163 | 1·161 | 1·158 | 1·156 | 1·154 |
| 1·166 | 1·164 | 1·162 | 1·160 | 1·157 | 1·155 | 1·153 | 1·151 | 1·148 | 1·146 | 1·144 |
| 1·156 | 1·154 | 1·152 | 1·150 | 1·148 | 1·146 | 1·144 | 1·142 | 1·140 | 1·137 | 1·135 |
| 1·146 | 1·144 | 1·142 | 1·140 | 1·138 | 1·136 | 1·134 | 1·132 | 1·130 | 1·127 | 1·125 |
| 1·136 | 1·134 | 1·132 | 1·130 | 1·128 | 1·126 | 1·124 | 1·122 | 1·120 | 1·118 | 1·116 |
| 1·126 | 1·124 | 1·122 | 1·120 | 1·118 | 1·116 | 1·114 | 1·112 | 1·110 | 1·108 | 1·106 |
| 1·115 | 1·113 | 1·112 | 1·110 | 1·108 | 1·106 | 1·104 | 1·102 | 1·100 | 1·099 | 1·097 |
| 1·105 | 1·103 | 1·102 | 1·100 | 1·098 | 1·096 | 1·095 | 1·093 | 1·092 | 1·090 | 1·087 |
| 1·094 | 1·093 | 1·091 | 1·090 | 1·088 | 1·087 | 1·086 | 1·084 | 1·082 | 1·080 | 1·078 |
| 1·084 | 1·083 | 1·081 | 1·080 | 1·078 | 1·077 | 1·076 | 1·074 | 1·072 | 1·070 | 1·068 |
| 1·074 | 1·073 | 1·071 | 1·070 | 1·068 | 1·067 | 1·066 | 1·064 | 1·062 | 1·060 | 1·058 |
| 1·064 | 1·063 | 1·061 | 1·060 | 1·058 | 1·057 | 1·056 | 1·054 | 1·052 | 1·050 | 1·048 |
| 1·054 | 1·053 | 1·051 | 1·050 | 1·048 | 1·047 | 1·046 | 1·044 | 1·042 | 1·040 | 1·038 |
| 1·044 | 1·043 | 1·041 | 1·040 | 1·038 | 1·037 | 1·036 | 1·034 | 1·032 | 1·030 | 1·028 |
| 1·034 | 1·033 | 1·031 | 1·030 | 1·028 | 1·027 | 1·026 | 1·024 | 1·022 | 1·020 | 1·018 |
| 1·024 | 1·023 | 1·021 | 1·020 | 1·018 | 1·017 | 1·016 | 1·014 | 1·012 | 1·010 | 1·008 |
| 1·014 | 1·013 | 1·011 | 1·010 | 1·008 | 1·007 | 1·006 | 1·004 | 1·002 | 1·000 | 0·998 |

GRAVITIES OF SOLUTIONS OF CAUSTIC SODA.

| 55°. | 60°. | 65°. | 70°. | 75°. | 80°. | 85°. | 90°. | 95°. | 100°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·839 | 1·386 | 1·333 | 1·331 | 1·328 | 1·326 | 1·323 | 1·321 | 1·318 | 1·316 |
| 1·830 | 1·327 | 1·324 | 1·322 | 1·319 | 1·316 | 1·314 | 1·311 | 1·308 | 1·306 |
| 1·820 | 1·317 | 1·314 | 1·312 | 1·309 | 1·306 | 1·304 | 1·301 | 1·298 | 1·296 |
| 1·810 | 1·307 | 1·304 | 1·302 | 1·299 | 1·296 | 1·294 | 1·291 | 1·288 | 1·286 |
| 1·800 | 1·297 | 1·294 | 1·292 | 1·289 | 1·286 | 1·283 | 1·280 | 1·277 | 1·274 |
| 1·289 | 1·286 | 1·284 | 1·281 | 1·278 | 1·275 | 1·272 | 1·269 | 1·266 | 1·263 |
| 1·270 | 1·276 | 1·274 | 1·271 | 1·268 | 1·265 | 1·262 | 1·259 | 1·256 | 1·253 |
| 1·269 | 1·266 | 1·264 | 1·261 | 1·258 | 1·255 | 1·252 | 1·249 | 1·245 | 1·242 |
| 1·259 | 1·256 | 1·254 | 1·251 | 1·248 | 1·245 | 1·242 | 1·239 | 1·235 | 1·232 |
| 1·250 | 1·247 | 1·245 | 1·242 | 1·239 | 1·236 | 1·233 | 1·231 | 1·228 | 1·225 |
| 1·240 | 1·237 | 1·235 | 1·232 | 1·229 | 1·226 | 1·223 | 1·221 | 1·218 | 1·215 |
| 1·231 | 1·228 | 1·226 | 1·223 | 1·220 | 1·218 | 1·215 | 1·213 | 1·209 | 1·207 |
| 1·221 | 1·218 | 1·216 | 1·213 | 1·210 | 1·208 | 1·205 | 1·203 | 1·200 | 1·197 |
| 1·210 | 1·208 | 1·205 | 1·202 | 1·200 | 1·198 | 1·195 | 1·192 | 1·190 | 1·187 |
| 1·200 | 1·198 | 1·195 | 1·192 | 1·190 | 1·188 | 1·185 | 1·182 | 1·180 | 1·177 |
| 1·191 | 1·189 | 1·186 | 1·184 | 1·181 | 1·179 | 1·176 | 1·173 | 1·171 | 1·168 |
| 1·182 | 1·180 | 1·177 | 1·175 | 1·172 | 1·169 | 1·166 | 1·163 | 1·161 | 1·158 |
| 1·172 | 1·169 | 1·166 | 1·164 | 1·161 | 1·158 | 1·155 | 1·153 | 1·150 | 1·147 |
| 1·162 | 1·159 | 1·156 | 1·153 | 1·151 | 1·148 | 1·145 | 1·143 | 1·140 | 1·137 |
| 1·152 | 1·149 | 1·146 | 1·143 | 1·140 | 1·138 | 1·135 | 1·132 | 1·130 | 1·127 |
| 1·142 | 1·139 | 1·136 | 1·133 | 1·130 | 1·128 | 1·125 | 1·122 | 1·120 | 1·117 |
| 1·132 | 1·130 | 1·127 | 1·124 | 1·121 | 1·118 | 1·116 | 1·113 | 1·110 | 1·107 |
| 1·122 | 1·120 | 1·117 | 1·114 | 1·111 | 1·108 | 1·106 | 1·103 | 1·100 | 1·097 |
| 1·118 | 1·110 | 1·107 | 1·104 | 1·101 | 1·099 | 1·096 | 1·093 | 1·090 | 1·087 |
| 1·103 | 1·100 | 1·097 | 1·094 | 1·092 | 1·089 | 1·086 | 1·083 | 1·080 | 1·077 |
| 1·094 | 1·091 | 1·089 | 1·086 | 1·083 | 1·080 | 1·077 | 1·074 | 1·071 | 1·068 |
| 1·084 | 1·082 | 1·079 | 1·076 | 1·073 | 1·070 | 1·067 | 1·064 | 1·061 | 1·058 |
| 1·075 | 1·073 | 1·070 | 1·067 | 1·064 | 1·061 | 1·058 | 1·056 | 1·052 | 1·048 |
| 1·066 | 1·063 | 1·060 | 1·057 | 1·054 | 1·051 | 1·048 | 1·046 | 1·043 | 1·040 |
| 1·056 | 1·053 | 1·050 | 1·047 | 1·044 | 1·042 | 1·039 | 1·036 | 1·033 | 1·030 |
| 1·046 | 1·043 | 1·040 | 1·037 | 1·034 | 1·032 | 1·029 | 1·026 | 1·023 | 1·020 |
| 1·036 | 1·033 | 1·030 | 1·027 | 1·024 | 1·021 | 1·019 | 1·016 | 1·013 | 1·010 |
| 1·026 | 1·023 | 1·020 | 1·017 | 1·014 | 1·011 | 1·009 | 1·006 | 1·003 | 1·000 |
| 1·016 | 1·013 | 1·010 | 1·007 | 1·004 | 1·001 | 0·999 | 0·996 | 0·993 | 0·990 |
| 1·006 | 1·003 | 1·000 | 0·997 | 0·994 | 0·991 | 0·989 | 0·986 | 0·983 | 0·980 |
| 0·996 | 0·993 | 0·990 | 0·987 | 0·984 | 0·981 | 0·979 | 0·976 | 0·973 | 0·970 |

B.—Lime Mud.

(a) *Sodium as Carbonate and Hydroxide*.—Evaporate to dryness with addition of ammonium carbonate (in order to decompose the insoluble sodium compounds), repeat this, digest with hot water, filter, wash, and test the filtrate for alkali. The soda may have been originally present as NaOH or as Na_2CO_3 . It is expressed in terms of Na_2O (0.03100 g. per cubic centimetre of normal acid).

(b) *Caustic Lime*.—Titrate as described (p. 184) with normal hydrochloric acid and phenolphthalein. This indicates NaOH as well, for which half of the amount found in test (a) may be assumed without any serious error.

(c) *Calcium Carbonate*.—Titrate with normal hydrochloric acid and methyl orange, deduct from the cubic centimetres required those required in tests (a) and (b).

C.—Fished Salts.

Dissolve 50 g. in 1 litre of water, and take 50 c.c. of the solution for every test.

(a) *Available Alkali* is tested for with normal hydrochloric acid.

(b) *Sodium Chloride*.—Neutralise with nitric acid, preferably running normal acid out of a burette, and proceed in other respects as described on p. 174.

(c) *Sodium Sulphate*.—Add a slight excess of hydrochloric acid, precipitate with barium chloride, and weigh the BaSO_4 (p. 134).

(d) *Sodium Sulphite, Thiosulphate, etc.*—Add an excess of bleaching-powder solution, then hydrochloric acid, till the reaction is acid, and a smell of chlorine is produced; precipitate with BaCl_2 , weigh the BaSO_4 , and deduct the amount found in test (c). The remainder is calculated as " Na_2SO_4 from oxidisable sulphur compounds."

D.—Caustic Bottoms.

Dissolve 10 g. in water, and filter. The washed residue is dried and ignited, and yields:—

(a) *Insoluble Matter*.—If necessary, the contained iron is estimated by dissolving in concentrated hydrochloric acid, reducing with zinc, adding manganous sulphate, and titrating with permanganate as on p. 137.

(b) *Available Alkali* is estimated in the aqueous solutions by normal hydrochloric acid, using litmus or lacmoid as indicator. (Methyl orange is not available in this case, owing to the presence of alumina.)

(c) *Sodium Carbonate* is estimated as in commercial soda ash (p. 190).

E.—Commercial Caustic Soda.

The sample must be very carefully taken. The single pieces must be freed from the outer crust by scraping it off, before weighing.

Dissolve 50 g. of the prepared sample in 1 litre of water, and take aliquot portions for each of the following tests with a pipette.

(a) *Available Alkali* is tested in at least 20 c.c. (equal to 1 g.) by normal HCl. If the caustic soda contains more than traces of alumina, methyl orange cannot be used as indicator, but litmus or lacmoid should be employed. In the case of strong caustic this is unnecessary.

(b) *Sodium Carbonate* is estimated by expelling the CO_2 with dilute sulphuric acid, and absorbing it in soda-lime (the pumice saturated with cupric sulphate is left out here). The quantity of CO_2 being so small, any estimation by difference yields unsatisfactory results. Very approximate results can, however, be obtained by titrating first with phenolphthalein till the pink colour is discharged (when all Na_2CO_3 will have been changed into NaHCO_3), noting the amount of standard acid used, adding methyl orange and more standard acid till the pink colour appears. The acid used in the second test $\times 2$ indicates Na_2CO_3 .

For more exact methods of determining carbonates, see Cumming and Kay's *Quantitative Analysis* (5th Edition), pp. 215 and 219.

(c) *The Table for comparing English, French, and German Degrees* is given on pp. 192 and 193.

X. ELECTROLYTIC ALKALI LIQUORS.

These are analysed just like bleach liquor, p. 189.

1. *Hypochlorites* are titrated as on p. 185.

2. *Free Hypochlorous Acid*.—Estimate the bleaching chlorine as in No. 1, then chloride, chlorate, and other acids on the one hand, and all bases on the other; the acidity in excess represents free HOCl .

3. *Chlorate* may be estimated as on p. 189, but since there is but little chlorate in presence of much hypochlorite, it is prefer-

able to use the direct method of Fresenius, as follows :—To the solution add an excess of neutral lead acetate solution ; this produces a precipitate which gradually turns brown, and which contains a quantity of PbO_2 corresponding to the chlorate. Allow to stand for eight or ten hours, until there is no more smell of chlorine, filter, wash, evaporate the filtrate to a small volume, precipitate lead and lime by means of a little sodium carbonate, and estimate the chlorate in the filtrate according to p. 189.

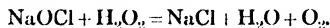
In mixtures of chlorate and hypochlorite, containing large quantities of the latter, Ditz and Knöpfelmacher estimate the chlorate iodometrically, by decomposing it at the ordinary temperature with concentrated hydrochloric acid and potassium bromide. Put the substance, together with a sufficient excess of KBr , into a small flask provided with a hollow glass stopper with dropping funnel and lateral absorbing vessel for the retention of bromine vapours. The latter is charged with 10 c.c. of a 5 per cent. solution of KI . Pour 50 c.c. concentrated hydrochloric acid through the dropping funnel into the flask, allow it to act for an hour, pour in 300 c.c. water, then 20 c.c. of the solution of KI , shake well, transfer the contents of the absorbing vessel to the flask, and titrate the iodine which has been set free by thiosulphate. The quantity of chlorate + hypochlorite is thus ascertained. If there is very much of the latter present, it should be removed beforehand.

4. *Chloride*.—Employ the solution from No. 1, in which all hypochlorite has been converted into chloride, with formation of sodium arsenate, which is an excellent indicator for the titration of the total chlorides by silver nitrate, p. 175, making *no* deduction for any excess of silver nitrate required to produce the colour. From the quantity of chloride thus found, deduct that which corresponds to the hypochlorite.

5. *Carbon Dioxide*.—Destroy the hypochlorite by boiling with ammonia, expel the CO_2 by a strong acid, and estimate it as on p. 209. The ammonia used must itself be free from carbonate.

6. *Bases*.—Convert these into sulphates, by evaporation with sulphuric acid, and estimate them in the residue by the ordinary methods.

7. *Free Alkali*.—Add to the solution a little of Merck's chemically pure hydrogen peroxide, which reacts as follows with the hypochlorite :—



NaOH and Na_2CO_3 remain unchanged in solution, and are titrated as on p. 202.

In regard to the estimation of carbon dioxide in electrolytic chlorine gas, see p. 187.

XI. NITRIC ACID MANUFACTURE.

A.—Commercial Nitrate of Soda.

According to the custom of the trade, which has held for many years, no direct estimation of the nitrate is made in the commercial nitrate of soda exported from Chili. The rule is, to estimate moisture, sodium chloride, sodium sulphate, and insoluble substances. The sum of these impurities is called the "refraction," and everything else is assumed to be real nitrate of soda. But as Chili saltpetre sometimes contains potassium nitrate (in which the percentage of NO_3 is less than in NaNO_3), errors up to 1 per cent. NaNO_3 or even more may be caused by this indirect method of testing. Therefore, besides the above estimations, it ought to be insisted upon to estimate the potassium present and to calculate the results accordingly, or even better, to estimate the nitric-nitrogen directly.

The *sampling* ought to be done very carefully, since especially the amount of moisture may vary considerably in different parts of a cargo, and the reduction of the large sample to a smaller bulk ought to yield a really representative average sample.

1. *Moisture*.—Heat 10 g. or more of a good average sample in a small glass or porcelain dish to 130° for four or five hours, till the weight is constant; or, about 0.5 g. is accurately weighed in a small silica crucible and heated gently over a Bunsen flame until the nitrate just fuses. The crucible is then cooled in a desiccator and re-weighed.

2. *Insoluble*.—Dissolve 10 g. in water, filter, wash, and ignite. If there is a very appreciable quantity of organic matter present, first dry at 100°C . and weigh the filter with the precipitate before igniting it. The solution is used for the tests Nos. 4 to 6.

3. *Sodium Nitrate*.—In order to obtain a really representative sample, take about 20 g. of the carefully taken, large, average sample, dry this at 110° , grind it very finely, mix it thoroughly, and use it for the estimation of nitrate, etc. For the nitrate test, weigh out about 0.35 g. (that is, a quantity which will yield between 100 and 120 c.c. NO at the ordinary temperature and barometric pressure) in a narrow weighing-tube. Pour its contents as completely as possible into the decomposition vessel D of the gas-volumeter, Fig. 12, p. 167, so that the substance gets as much as possible to the bottom of the beaker of D. Weigh the weighing-tube again, with the small quantity of nitrate still adhering to it, so as to ascertain the weight of nitrate taken = a , in D. The three-way tap must be closed. Now run in 0.5 c.c. water, wait until the nitrate has been entirely or nearly all dis-

solved, draw the solution with any small crystals into the inside of D, by lowering the level-tube E and cautiously opening the tap, rinse the beaker with $\frac{1}{2}$ or at most 1 c.c. water, and then allow 15 c.c. of pure concentrated sulphuric acid to enter in the same way. (It is important not to employ more than 1.5 c.c. water altogether to 15 c.c. of strong acid, for if the acid is too much diluted, a froth of basic mercuric sulphate is formed which prevents an exact reading of the volume. On the other hand, the addition of a little water to the strong acid prevents the solution of an appreciable quantity of NO in the liquid.)

The reaction is finished by vigorous shaking of the acid solution with the mercury (as in the ordinary nitrometer). During this period the level-tube should be roughly put into position, to avoid any considerable differences of pressure and possible leakages through the tap. When the agitating has been finished wait half an hour for cooling. Then connect tube c of vessel D (Fig. 12, p. 167) with tube e of the measuring tube A, so that glass touches glass, as described p. 168, and transfer all the gas to A, by raising E and lowering C, but not allowing any acid to get into A. Then shut both taps, and by adjusting the tubes A, B, C, in the manner described, p. 168, compress the gas volume to that corresponding to 0° and 760 mm. pressure.

Of course it is also possible to employ, in lieu of the gas-volumeter, an ordinary nitrometer, that is, to leave out the "reduction-tube" B. In this case the volume NO is read off under the prevailing atmospheric pressure, by adjusting the level-tube accordingly; the volume of NO is then reduced to 0° and 760 mm. by reading the thermometer and barometer, and employing the Tables 12, I. and II., pp. 20 *et seq.* The reduced volume of NO we call x . Each c.c. of it corresponds to 0.0037963 g. NaNO_3 (compare the table, p. 20); the whole divided by the weight of the nitrate employed a and multiplied by 100, indicates the percentage of real nitrate; that is:—

$$\frac{0.37963x}{a}$$

A plus correction of 0.4 per cent. of the NaNO_3 found is necessary to allow for the solubility of NO.

(*N.B.*—The nitrometer should be tested whether it really contains exactly 100 c.c. to the mark 100, by inverting it, filling in mercury to the mark 100, running it off, and weighing. It should weigh 1360 g. reduced to 0°, or 1355 g. at 15° C. If there is an error, this must be allowed for in each reading.)

4. *Sodium Sulphate* is estimated in the solution No. 2 by precipitation with BaCl_2 and weighing the BaSO_4 . (*Cf.* pp. 134 and 176.)

5. *Sodium Chloride* is titrated with silver nitrate. (Cf. p. 174.)

6. *Iodine* is detected by reducing the iodic acid with zinc, heating the solution with concentrated sulphuric acid, which liberates the iodine, diluting and agitating with carbon disulphide, which takes up the iodine, and is thereby coloured pink. The faintest traces of iodate are found by dissolving 5 g. in 100 c.c. of boiled water, adding a little nitric acid, a few drops of a solution of potassium iodide in boiled water, and a drop of starch solution. In the presence of as little as 0.01 mg. I in 1 g. of nitre, a blue colour will appear. A check test must, however, be made with the potassium iodide employed for this test, as this often contains some iodate.

7. *Potassium*.—Evaporate a special sample several times, with strong hydrochloric acid until all the nitrate is decomposed, and estimate the K as in the analysis of potassium chloride, p. 221. Calculate it as KNO_3 , 100 parts of which is equivalent to 84.08 of NaNO_3 .

8. *Perchlorate* (Gilbert).—Treat 20 g. of the dried substance with 2 or 3 c.c. concentrated hydrochloric acid in a flat platinum dish; add about 1 g. manganese dioxide, free from chlorine, dry by heating over a small flame; bring to fusion, put on the lid and keep the dish at a red heat during one-quarter hour. Dissolve the melt in hot water and dilute the solution to 250 c.c. Take out 50 c.c. (= 4 g. nitre), acidulate with nitric acid and add a 1 per cent. solution of KMnO_4 , until the red colour persists for a full minute. Then add ferric potassium sulphate (iron alum), and titrate the chloride by means of silver nitrate (Volhard's method). From the Cl thus found, deduct that which was originally present (No. 5), and calculate the remainder as perchlorate. 1 part NaCl corresponds to 2.095 NaClO_4 .

B.—Nitre-Cake.

1. *Free Acid* is titrated with standard alkali (p. 175). If considerable quantities of ferric oxide or alumina are present, no indicator is employed, but normal alkali is added till the first flakes of a precipitate indicate the end of the reaction.

2. *Nitric Acid* should be estimated in a nitrometer with a narrow measuring-tube (p. 165); the method employed is exactly the same as described there, viz., dissolving in the beaker in very little water, and decomposing with a large excess of sulphuric acid.

3. *Ferric Oxide and Alumina* (as pp. 170 and 175).

C.—Nitric Acid.

1. SPECIFIC GRAVITY OF NITRIC ACID AT 15° C., COMPARED WITH WATER OF 4° C. (IN VACUO).

(Lunge and Rey.)

| Degrees Twad- dell. | Specific gravity. | Percentage by weight. | | Grams per litre. | |
|---------------------------|----------------------|---------------------------------|--------------------|---------------------------------|--------------------|
| | | N ₂ O ₅ . | HNO ₃ . | N ₂ O ₅ . | HNO ₃ . |
| 0 | 1·000 | 0·08 | 0·10 | 1 | 1 |
| 1 | 1·005 | 0·85 | 1·00 | 8 | 10 |
| 2 | 1·010 | 1·62 | 1·90 | 16 | 19 |
| 3 | 1·015 | 2·39 | 2·80 | 24 | 28 |
| 4 | 1·020 | 3·17 | 3·70 | 33 | 38 |
| 5 | 1·025 | 3·94 | 4·60 | 40 | 47 |
| 6 | 1·030 | 4·71 | 5·50 | 49 | 57 |
| 7 | 1·035 | 5·47 | 6·38 | 57 | 66 |
| 8 | 1·040 | 6·22 | 7·26 | 64 | 75 |
| 9 | 1·045 | 6·97 | 8·13 | 73 | 85 |
| 10 | 1·050 | 7·71 | 8·99 | 81 | 94 |
| 11 | 1·055 | 8·43 | 9·84 | 89 | 104 |
| 12 | 1·060 | 9·15 | 10·68 | 97 | 113 |
| 13 | 1·065 | 9·87 | 11·51 | 105 | 123 |
| 14 | 1·070 | 10·57 | 12·33 | 113 | 132 |
| 15 | 1·075 | 11·27 | 13·15 | 121 | 141 |
| 16 | 1·080 | 11·96 | 13·95 | 129 | 151 |
| 17 | 1·085 | 12·64 | 14·74 | 137 | 160 |
| 18 | 1·090 | 13·31 | 15·53 | 145 | 169 |
| 19 | 1·095 | 13·99 | 16·32 | 153 | 179 |
| 20 | 1·100 | 14·67 | 17·11 | 161 | 188 |
| 21 | 1·105 | 15·34 | 17·89 | 170 | 198 |
| 22 | 1·110 | 16·00 | 18·67 | 177 | 207 |
| 23 | 1·115 | 16·67 | 19·45 | 186 | 217 |
| 24 | 1·120 | 17·34 | 20·23 | 195 | 227 |
| 25 | 1·125 | 18·00 | 21·00 | 202 | 236 |
| 26 | 1·130 | 18·66 | 21·77 | 211 | 246 |
| 27 | 1·135 | 19·32 | 22·54 | 219 | 256 |
| 28 | 1·140 | 19·98 | 23·31 | 228 | 266 |
| 29 | 1·145 | 20·64 | 24·08 | 237 | 276 |
| 30 | 1·150 | 21·29 | 24·84 | 245 | 286 |
| 31 | 1·155 | 21·94 | 25·60 | 254 | 296 |
| 32 | 1·160 | 22·60 | 26·36 | 262 | 306 |
| 33 | 1·165 | 23·25 | 27·12 | 271 | 316 |
| 34 | 1·170 | 23·90 | 27·88 | 279 | 326 |

**SPECIFIC GRAVITY OF NITRIC ACID AT 15° C., COMPARED
WITH WATER OF 4° C. (IN VACUO)—Continued.**

| Degrees Twad- dell. | Specific gravity. | Percentage by weight. | | Grams per litre. | |
|---------------------------|----------------------|---------------------------------|--------------------|---------------------------------|--------------------|
| | | N ₂ O ₅ . | HNO ₃ . | N ₂ O ₅ . | HNO ₃ . |
| 35 | 1·175 | 24·54 | 28·63 | 288 | 336 |
| 36 | 1·180 | 25·18 | 29·38 | 297 | 347 |
| 37 | 1·185 | 25·83 | 30·13 | 306 | 357 |
| 38 | 1·190 | 26·47 | 30·88 | 315 | 367 |
| 39 | 1·195 | 27·10 | 31·62 | 324 | 378 |
| 40 | 1·200 | 27·74 | 32·36 | 333 | 388 |
| 41 | 1·205 | 28·36 | 33·09 | 342 | 399 |
| 42 | 1·210 | 28·99 | 33·82 | 351 | 409 |
| 43 | 1·215 | 29·61 | 34·55 | 360 | 420 |
| 44 | 1·220 | 30·24 | 35·28 | 369 | 430 |
| 45 | 1·225 | 30·88 | 36·03 | 378 | 441 |
| 46 | 1·230 | 31·53 | 36·78 | 387 | 452 |
| 47 | 1·235 | 32·17 | 37·53 | 397 | 463 |
| 48 | 1·240 | 32·82 | 38·29 | 407 | 475 |
| 49 | 1·245 | 33·47 | 39·05 | 417 | 486 |
| 50 | 1·250 | 34·13 | 39·82 | 427 | 498 |
| 51 | 1·255 | 34·78 | 40·58 | 437 | 509 |
| 52 | 1·260 | 35·44 | 41·34 | 447 | 521 |
| 53 | 1·265 | 36·09 | 42·10 | 457 | 533 |
| 54 | 1·270 | 36·75 | 42·87 | 467 | 544 |
| 55 | 1·275 | 37·41 | 43·64 | 477 | 556 |
| 56 | 1·280 | 38·07 | 44·41 | 487 | 568 |
| 57 | 1·285 | 38·73 | 45·18 | 498 | 581 |
| 58 | 1·290 | 39·39 | 45·95 | 508 | 593 |
| 59 | 1·295 | 40·05 | 46·72 | 519 | 605 |
| 60 | 1·300 | 40·71 | 47·49 | 529 | 617 |
| 61 | 1·305 | 41·37 | 48·26 | 540 | 630 |
| 62 | 1·310 | 42·06 | 49·07 | 551 | 643 |
| 63 | 1·315 | 42·76 | 49·89 | 562 | 656 |
| 64 | 1·320 | 43·47 | 50·71 | 573 | 669 |
| 65 | 1·325 | 44·17 | 51·53 | 585 | 683 |
| 66 | 1·330 | 44·89 | 52·37 | 597 | 697 |
| 67 | 1·335 | 45·62 | 53·22 | 609 | 710 |
| 68 | 1·340 | 46·35 | 54·07 | 621 | 725 |
| 69 | 1·345 | 47·08 | 54·93 | 633 | 739 |

**SPECIFIC GRAVITY OF NITRIC ACID AT 15° C., COMPARED
WITH WATER OF 4° C. (IN VACUO)—Continued.**

| Degrées Twad- dell. | Specific gravity. | Percentage by weight. | | Grams per litre. | |
|---------------------------|----------------------|---------------------------------|--------------------|---------------------------------|--------------------|
| | | N ₂ O ₅ . | HNO ₃ . | N ₂ O ₅ . | HNO ₃ . |
| 70 | 1·350 | 47·82 | 55·79 | 645 | 753 |
| 71 | 1·355 | 48·57 | 56·66 | 658 | 768 |
| 72 | 1·360 | 49·35 | 57·57 | 671 | 783 |
| 73 | 1·365 | 50·13 | 58·48 | 684 | 798 |
| 74 | 1·370 | 50·91 | 59·39 | 698 | 814 |
| 75 | 1·375 | 51·69 | 60·30 | 711 | 829 |
| 76 | 1·380 | 52·52 | 61·27 | 725 | 846 |
| 77 | 1·385 | 53·35 | 62·24 | 739 | 862 |
| 78 | 1·390 | 54·20 | 63·23 | 753 | 879 |
| 79 | 1·395 | 55·07 | 64·25 | 768 | 896 |
| 80 | 1·400 | 55·97 | 65·30 | 783 | 914 |
| 81 | 1·405 | 56·92 | 66·40 | 800 | 933 |
| 82 | 1·410 | 57·86 | 67·50 | 816 | 952 |
| 83 | 1·415 | 58·83 | 68·63 | 832 | 971 |
| 84 | 1·420 | 59·83 | 69·80 | 849 | 991 |
| 85 | 1·425 | 60·84 | 70·98 | 867 | 1011 |
| 86 | 1·430 | 61·86 | 72·17 | 885 | 1032 |
| 87 | 1·435 | 62·91 | 73·39 | 903 | 1053 |
| 88 | 1·440 | 64·01 | 74·68 | 921 | 1075 |
| 89 | 1·445 | 65·13 | 75·98 | 941 | 1098 |
| 90 | 1·450 | 66·24 | 77·28 | 961 | 1121 |
| 91 | 1·455 | 67·38 | 78·60 | 981 | 1144 |
| 92 | 1·460 | 68·56 | 79·98 | 1001 | 1168 |
| 93 | 1·465 | 69·79 | 81·42 | 1023 | 1193 |
| 94 | 1·470 | 71·06 | 82·90 | 1045 | 1219 |
| 95 | 1·475 | 72·39 | 84·45 | 1068 | 1246 |
| 96 | 1·480 | 73·76 | 86·05 | 1092 | 1274 |
| 97 | 1·485 | 75·18 | 87·70 | 1116 | 1302 |
| 98 | 1·490 | 76·80 | 89·60 | 1144 | 1335 |
| 99 | 1·495 | 78·52 | 91·60 | 1174 | 1369 |
| 100 | 1·500 | 80·65 | 94·09 | 1210 | 1411 |
| 101 | 1·505 | 82·63 | 96·39 | 1244 | 1451 |
| 102 | 1·510 | 84·09 | 98·10 | 1270 | 1481 |
| 103 | 1·515 | 84·92 | 99·07 | 1287 | 1501 |
| 104 | 1·520 | 85·44 | 99·67 | 1299 | 1515 |

2. INFLUENCE OF TEMPERATURE ON THE SPECIFIC GRAVITY OF NITRIC ACID.

| 0° C. | 5° | 10° | 15° | 20° | 25° | 30° | 35° | 40° | 45° | 50° |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·424 | 1·414 | 1·407 | 1·400 | 1·392 | 1·385 | 1·378 | 1·371 | 1·363 | 1·356 | 1·349 |
| 1·413 | 1·404 | 1·397 | 1·390 | 1·382 | 1·375 | 1·367 | 1·361 | 1·354 | 1·347 | 1·340 |
| 1·402 | 1·394 | 1·387 | 1·380 | 1·372 | 1·365 | 1·357 | 1·351 | 1·344 | 1·339 | 1·332 |
| 1·391 | 1·383 | 1·377 | 1·370 | 1·363 | 1·356 | 1·349 | 1·342 | 1·335 | 1·330 | 1·323 |
| 1·380 | 1·373 | 1·367 | 1·360 | 1·353 | 1·346 | 1·340 | 1·333 | 1·326 | 1·320 | 1·314 |
| 1·369 | 1·362 | 1·356 | 1·350 | 1·343 | 1·337 | 1·330 | 1·323 | 1·317 | 1·312 | 1·305 |
| 1·359 | 1·352 | 1·346 | 1·340 | 1·333 | 1·327 | 1·320 | 1·314 | 1·308 | 1·303 | 1·297 |
| 1·348 | 1·342 | 1·336 | 1·330 | 1·324 | 1·318 | 1·311 | 1·305 | 1·299 | 1·294 | 1·288 |
| 1·338 | 1·332 | 1·326 | 1·320 | 1·314 | 1·308 | 1·302 | 1·296 | 1·290 | 1·285 | 1·280 |
| 1·327 | 1·321 | 1·316 | 1·310 | 1·304 | 1·299 | 1·293 | 1·287 | 1·281 | 1·276 | 1·271 |
| 1·317 | 1·311 | 1·306 | 1·300 | 1·294 | 1·289 | 1·283 | 1·278 | 1·273 | 1·268 | 1·263 |
| 1·307 | 1·301 | 1·296 | 1·290 | 1·284 | 1·279 | 1·273 | 1·268 | 1·263 | 1·258 | 1·253 |
| 1·297 | 1·291 | 1·286 | 1·280 | 1·274 | 1·269 | 1·263 | 1·258 | 1·253 | 1·248 | 1·243 |
| 1·287 | 1·281 | 1·276 | 1·270 | 1·265 | 1·259 | 1·254 | 1·248 | 1·243 | 1·238 | 1·234 |
| 1·277 | 1·271 | 1·266 | 1·260 | 1·255 | 1·249 | 1·244 | 1·238 | 1·233 | 1·228 | 1·224 |
| 1·266 | 1·260 | 1·255 | 1·250 | 1·245 | 1·240 | 1·235 | 1·229 | 1·224 | 1·219 | 1·215 |
| 1·256 | 1·250 | 1·245 | 1·240 | 1·235 | 1·230 | 1·225 | 1·220 | 1·215 | 1·210 | 1·205 |
| 1·245 | 1·240 | 1·235 | 1·230 | 1·225 | 1·220 | 1·215 | 1·210 | 1·206 | 1·201 | 1·196 |
| 1·235 | 1·230 | 1·225 | 1·220 | 1·215 | 1·210 | 1·205 | 1·200 | 1·196 | 1·191 | 1·186 |
| 1·224 | 1·219 | 1·214 | 1·210 | 1·205 | 1·200 | 1·196 | 1·191 | 1·187 | 1·182 | 1·177 |
| 1·213 | 1·208 | 1·204 | 1·200 | 1·195 | 1·190 | 1·186 | 1·181 | 1·177 | 1·172 | 1·167 |
| 1·202 | 1·198 | 1·194 | 1·190 | 1·185 | 1·181 | 1·177 | 1·172 | 1·168 | 1·163 | 1·158 |
| 1·192 | 1·188 | 1·184 | 1·180 | 1·177 | 1·171 | 1·167 | 1·163 | 1·158 | 1·154 | 1·150 |
| 1·182 | 1·178 | 1·174 | 1·170 | 1·166 | 1·162 | 1·158 | 1·154 | 1·149 | 1·145 | 1·141 |
| 1·172 | 1·168 | 1·164 | 1·160 | 1·156 | 1·152 | 1·148 | 1·144 | 1·140 | 1·136 | 1·132 |
| 1·161 | 1·158 | 1·154 | 1·150 | 1·146 | 1·142 | 1·139 | 1·135 | 1·130 | 1·127 | 1·123 |
| 1·151 | 1·147 | 1·144 | 1·140 | 1·136 | 1·132 | 1·129 | 1·125 | 1·121 | 1·118 | 1·114 |
| 1·139 | 1·136 | 1·133 | 1·130 | 1·126 | 1·123 | 1·119 | 1·116 | 1·112 | 1·109 | 1·105 |
| 1·129 | 1·126 | 1·123 | 1·120 | 1·116 | 1·113 | 1·110 | 1·106 | 1·103 | 1·100 | 1·096 |
| 1·118 | 1·115 | 1·112 | 1·110 | 1·107 | 1·104 | 1·101 | 1·097 | 1·094 | 1·091 | 1·087 |
| 1·108 | 1·105 | 1·102 | 1·100 | 1·097 | 1·094 | 1·091 | 1·088 | 1·085 | 1·082 | 1·079 |
| 1·098 | 1·095 | 1·092 | 1·090 | 1·087 | 1·084 | 1·081 | 1·078 | 1·075 | 1·073 | 1·070 |
| 1·088 | 1·085 | 1·082 | 1·080 | 1·077 | 1·074 | 1·071 | 1·068 | 1·065 | 1·063 | 1·060 |
| 1·077 | 1·075 | 1·072 | 1·070 | 1·067 | 1·064 | 1·061 | 1·058 | 1·056 | 1·054 | 1·051 |
| 1·067 | 1·064 | 1·062 | 1·060 | 1·057 | 1·055 | 1·052 | 1·050 | 1·048 | 1·045 | 1·043 |
| 1·057 | 1·054 | 1·052 | 1·050 | 1·047 | 1·045 | 1·043 | 1·040 | 1·038 | 1·035 | 1·033 |
| 1·047 | 1·044 | 1·042 | 1·040 | 1·037 | 1·035 | 1·033 | 1·030 | 1·028 | 1·025 | 1·023 |
| 1·037 | 1·034 | 1·032 | 1·030 | 1·027 | 1·025 | 1·023 | 1·020 | 1·018 | 1·015 | 1·013 |
| 1·027 | 1·024 | 1·022 | 1·020 | 1·017 | 1·015 | 1·013 | 1·010 | 1·008 | 1·005 | 1·003 |
| 1·017 | 1·014 | 1·012 | 1·010 | 1·007 | 1·005 | 1·003 | 1·000 | 0·998 | 0·995 | 0·993 |

**INFLUENCE OF TEMPERATURE ON THE SPECIFIC
GRAVITY OF NITRIC ACID—Continued.**

| 55° | 60° | 65° | 70° | 75° | 80° | 85° | 90° | 95° | 100° |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1.842 | 1.835 | 1.829 | 1.823 | 1.816 | 1.810 | 1.803 | 1.296 | 1.290 | 1.283 |
| 1.833 | 1.827 | 1.820 | 1.814 | 1.808 | 1.802 | 1.294 | 1.288 | 1.282 | 1.276 |
| 1.825 | 1.819 | 1.812 | 1.805 | 1.800 | 1.293 | 1.286 | 1.280 | 1.274 | 1.267 |
| 1.816 | 1.810 | 1.804 | 1.298 | 1.292 | 1.286 | 1.279 | 1.274 | 1.267 | 1.260 |
| 1.808 | 1.802 | 1.296 | 1.290 | 1.284 | 1.278 | 1.272 | 1.266 | 1.260 | 1.254 |
| 1.800 | 1.294 | 1.288 | 1.282 | 1.276 | 1.270 | 1.265 | 1.259 | 1.253 | 1.247 |
| 1.291 | 1.286 | 1.280 | 1.274 | 1.268 | 1.263 | 1.257 | 1.252 | 1.246 | 1.240 |
| 1.282 | 1.278 | 1.272 | 1.266 | 1.261 | 1.255 | 1.250 | 1.245 | 1.240 | 1.234 |
| 1.274 | 1.269 | 1.264 | 1.258 | 1.253 | 1.248 | 1.243 | 1.238 | 1.233 | 1.228 |
| 1.266 | 1.261 | 1.256 | 1.251 | 1.246 | 1.240 | 1.235 | 1.230 | 1.225 | 1.220 |
| 1.258 | 1.253 | 1.248 | 1.243 | 1.238 | 1.232 | 1.227 | 1.222 | 1.217 | 1.212 |
| 1.248 | 1.244 | 1.239 | 1.234 | 1.229 | 1.223 | 1.218 | 1.213 | 1.208 | 1.203 |
| 1.238 | 1.234 | 1.229 | 1.224 | 1.219 | 1.214 | 1.209 | 1.204 | 1.199 | 1.194 |
| 1.229 | 1.225 | 1.220 | 1.215 | 1.210 | 1.205 | 1.199 | 1.195 | 1.190 | 1.185 |
| 1.219 | 1.215 | 1.210 | 1.205 | 1.200 | 1.195 | 1.190 | 1.185 | 1.180 | 1.175 |
| 1.210 | 1.206 | 1.201 | 1.196 | 1.191 | 1.186 | 1.181 | 1.176 | 1.171 | 1.167 |
| 1.200 | 1.196 | 1.191 | 1.186 | 1.181 | 1.177 | 1.172 | 1.167 | 1.162 | 1.158 |
| 1.191 | 1.187 | 1.182 | 1.177 | 1.172 | 1.168 | 1.163 | 1.158 | 1.153 | 1.149 |
| 1.182 | 1.177 | 1.172 | 1.167 | 1.163 | 1.158 | 1.153 | 1.148 | 1.144 | 1.139 |
| 1.173 | 1.168 | 1.163 | 1.160 | 1.154 | 1.149 | 1.144 | 1.140 | 1.135 | 1.130 |
| 1.163 | 1.158 | 1.154 | 1.150 | 1.145 | 1.140 | 1.136 | 1.131 | 1.126 | 1.122 |
| 1.154 | 1.150 | 1.146 | 1.141 | 1.136 | 1.132 | 1.128 | 1.123 | 1.119 | 1.115 |
| 1.145 | 1.141 | 1.137 | 1.133 | 1.128 | 1.124 | 1.120 | 1.116 | 1.112 | 1.107 |
| 1.137 | 1.132 | 1.128 | 1.124 | 1.120 | 1.116 | 1.113 | 1.108 | 1.105 | 1.100 |
| 1.128 | 1.124 | 1.120 | 1.116 | 1.112 | 1.108 | 1.105 | 1.101 | 1.097 | 1.094 |
| 1.119 | 1.115 | 1.112 | 1.108 | 1.104 | 1.100 | 1.097 | 1.095 | 1.090 | 1.086 |
| 1.110 | 1.107 | 1.103 | 1.100 | 1.096 | 1.093 | 1.090 | 1.086 | 1.082 | 1.079 |
| 1.102 | 1.099 | 1.094 | 1.091 | 1.088 | 1.084 | 1.081 | 1.078 | 1.075 | 1.071 |
| 1.093 | 1.090 | 1.086 | 1.083 | 1.080 | 1.076 | 1.073 | 1.070 | 1.067 | 1.064 |
| 1.084 | 1.081 | 1.078 | 1.075 | 1.072 | 1.068 | 1.065 | 1.063 | 1.060 | 1.056 |
| 1.076 | 1.073 | 1.070 | 1.067 | 1.064 | 1.061 | 1.058 | 1.055 | 1.052 | 1.049 |
| 1.067 | 1.064 | 1.061 | 1.058 | 1.055 | 1.052 | 1.050 | 1.048 | 1.045 | 1.042 |
| 1.058 | 1.055 | 1.052 | 1.050 | 1.047 | 1.044 | 1.042 | 1.040 | 1.038 | 1.036 |
| 1.049 | 1.046 | 1.044 | 1.042 | 1.039 | 1.037 | 1.034 | 1.031 | 1.029 | 1.027 |
| 1.040 | 1.038 | 1.036 | 1.034 | 1.031 | 1.029 | 1.026 | 1.023 | 1.021 | 1.018 |
| 1.030 | 1.028 | 1.026 | 1.024 | 1.021 | 1.019 | 1.015 | 1.014 | 1.012 | 1.009 |
| 1.020 | 1.018 | 1.016 | 1.014 | 1.011 | 1.009 | 1.007 | 1.004 | 1.002 | 1.000 |
| 1.010 | 1.008 | 1.006 | 1.004 | 1.001 | 0.999 | 0.997 | 0.994 | 0.993 | 0.990 |
| 1.001 | 0.999 | 0.997 | 0.995 | 0.992 | 0.990 | 0.988 | 0.985 | 0.983 | 0.981 |
| 0.991 | 0.989 | 0.987 | 0.985 | 0.982 | 0.980 | 0.978 | 0.975 | 0.973 | 0.971 |

3. *Total Acidity*.—Titrate a diluted sample by standard caustic soda solution. Methyl orange can be quite well used as indicator, if the titration is performed as described, p. 162, although it would be destroyed by prolonged contact with nitrous acid. Strong fuming acid is weighed in a bulb-tap pipette, Fig. 13, p. 171; from this the acid is slowly run on to the bottom of a flask, containing ice-cold water, and the titration is performed quickly, to prevent a decomposition of the nitrous acid. Less concentrated nitric acids may be measured by pipettes or burettes, in lieu of weighing.

4. *Chlorine*.—Saturate with sodium carbonate, free from chloride, till the reaction is neutral or faintly alkaline, and titrate with silver nitrate according to p. 174.

5. *Sulphuric Acid*.—Saturate almost completely with sodium carbonate and precipitate with barium chloride as on p. 134. If the acid on evaporating leaves any appreciable fixed residue, this usually consists of sodium sulphate.

6. *Nitrous Acid* or *Nitrogen Tetroxide* are estimated by running the acid from a burette into a measured volume of warm, dilute potassium permanganate (*cf.* p. 162). The result may be expressed in terms of nitrogen peroxide, N_2O_4 . Each c.c. $\frac{1}{2}$ normal permanganate = 0.023005 g. N_2O_4 . Hence, if m c.c. acid have been used and n c.c. permanganate required, the amount of N_2O_4 is:—

$$\frac{0.023005}{m} n \text{ g.}$$

The result may also be expressed as nitrous acid calculated to HNO_3 . Each c.c. $\frac{1}{2}$ normal permanganate = 0.011755 g. HNO_2 and the factor for conversion to HNO_3 = 1.34.

The quantity of N_2O_4 is often so considerable that the specific gravity tables give a very deceptive result as to the real percentage of HNO_3 , and an actual determination should be made.

7. *Fixed Residue*, consisting chiefly of sodium sulphate, with a little ferric oxide, etc., is estimated by evaporating to dryness in a place protected from dust, igniting, and weighing.

8. *Iron*.—Precipitate with excess of ammonia, filter, weigh, and ignite the Fe_2O_3 .

9. *Iodine* is detected by digesting for a short time with pure zinc, which reduces iodic acid and generates some nitrous acid; the latter sets the iodine of the HI free, and this can then be recognised by shaking up with carbon disulphide, which thereby assumes a pink colour.

N.B.—Tests Nos. 8 and 9 are only made with nitric acid sold as chemically pure.

D.—Mixtures of Sulphuric Acid and Nitric Acid.

Such mixtures are sold for the manufacture of explosives and other nitrating purposes. They are analysed by the methods described by Lunge and Berl, *Z. angew. Chem.*, 1905, p. 1681; *Chem. Zeit.*, 1907, p. 485.

1. *Total Acidity*.—Weigh about 1 g. in a bulb-tap pipette, Fig. 13, p. 171, and titrate with normal caustic soda solution. When employing methyl orange as indicator, either add it only towards the end of the titration (or else renew it as destroyed), or else add an excess of soda, then the indicator, and titrate back with normal hydrochloric acid.

2. *Nitrous Acid* is estimated as on p. 162, by running the mixed acid into a measured quantity of seminormal permanganate. It may be calculated as HNO_2 , or N_2O_3 , or even as N_2O_4 . In the latter case each c.c. of the $\frac{1}{2}$ normal permanganate indicates 0.023005 g. N_2O_4 . If we call the c.c. of permanganate used x , the c.c. of mixed acid required for decolorising it y , and s the specific gravity of the latter, the N_2O_4 is = $\frac{23 \cdot x}{y \cdot s}$ g. per litre, or $\frac{2 \cdot 3 \cdot x}{y \cdot s}$ per cent. by weight of N_2O_4 in the mixed acid.

3. Total nitrogen acids are estimated by the nitrometer, p. 165. A quantity of acid, varying with the nature of the mixed acid being analysed, is weighed by difference into the cup of a calibrated nitrometer to which 2 c.c. of pure nitrogen-free 94.5 per cent. sulphuric acid has previously been added. A Lunge-Rey pipette is used for this purpose. The sample is then run into the nitrometer and the cup thoroughly washed by five successive washings of 2 c.c. of sulphuric acid, followed by a sixth washing of 5 c.c. The decomposition is effected in the usual way. The observed volume of gas is reduced to N.T.P. and the result calculated as percentage of nitric acid (HNO_3). Each c.c. NO at N.T.P. corresponds to 0.0028144 g. HNO_3 , so that the percentage total nitrogen acids expressed as nitric acid is given by the formula

$$v \times 0.0028144 \times 100 \\ w$$

where v = volume of NO and w = weight of mixed acid taken.

A plus correction of 1 per cent. of the total nitrogen acids found is necessary to allow for the solubility of NO.

4. Nitric acid is obtained by subtracting the nitrous acid (as HNO_2) from the total nitrogen acids (as HNO_3).

5. Sulphuric acid is found by subtracting the value for the total nitrogen acids expressed as H_2SO_4 from the total acidity also expressed as H_2SO_4 . For this purpose the percentage of total nitrogen acids expressed as HNO_3 is multiplied by 0.778 which represents the ratio between equivalent weights of sulphuric acid and nitric acid, $\frac{1}{2}\text{H}_2\text{SO}_4 : \text{HNO}_3$.

XII.—POTASSIUM SALTS.

A.—Crude Salts (Carnallite, Kainite, etc.).

1. *Moisture*.—Heat 10 g. to 150° for some time, and allow to cool in a desiccator.

2. *Percentage of Potassium* : *—

(a) *In the Absence of more than 0.5 per cent. Potassium Sulphate*.—Obtain a well-mixed sample; dissolve 7.640 g. in a half-litre flask, fill up to the mark, and filter. Place 20 c.c. of the filtrate (= 0.3056 of the crude salt) in a porcelain dish; add 5 c.c. of a solution of platinum chloride containing 10 g. Pt. in 100 c.c. Evaporate on the water-bath to a syrupy condition, with frequent agitation, so that most of the HCl is driven off and the mass appears dry after cooling. When cool, crush it with a flattened glass rod, add 20 c.c. strong alcohol (at least 94 per cent.), mix well through and pour the liquid portion through a filter which has been previously dried at 120° to 130° till the weight is constant, then weighed and moistened with alcohol. The filter should not be filled up to the top. Pour fresh alcohol on the residue, and heat it on the water-bath nearly to boiling. Wash the solid portion on to the filter, remove most of the liquid by suction, press it between layers of filter paper and dry it till the weight is constant at 120° to 130° (this will usually require only twenty minutes). Each milligram of the potassium-platinum chloride corresponds to 0.1 per cent. KCl in the quantity of substance employed.

(b) *In the Presence of more than 0.5 per cent. Potassium Sulphate*.—Dissolve 30.56 g. of the crude salt in a $\frac{1}{2}$ -litre flask in 300 c.c. water + 15 c.c. strong hydrochloric acid by boiling, allow to cool, and fill the flask up to the mark. Put 50 c.c. of the clear

* These are the methods given by Tietjens in *Tech. Meth.*, vol. i., p. 520, as worked out and practised at all the Stassfurt works. This applies also to the figures employed for the calculation of the results which are not based on the real atomic weight of platinum (= 194.80) and on the formula K_2PtCl_6 , but are empirical data, based on many years' experience. The difference is mainly caused by the fact that the precipitate is not pure K_2PtCl_6 , but contains some chemically combined water which is not given up even after prolonged drying.

solution into a 200 c.c. flask, heat to boiling, and precipitate the sulphate with the exactly necessary quantity of barium chloride, adding the principal portion of the reagent quickly, the remainder in single drops, always waiting till the liquid shows a clear layer and throwing into this a minute crystal of barium chloride, until this ceases to produce a cloud. If too much BaCl_2 should have been accidentally added, it must be removed by a drop or two of dilute sulphuric acid. After cooling, fill up to the mark and take 20 c.c. of the clear solution = 0.3056 g. salt, which is then treated with platinum chloride as described in No. 1. One mg. of the precipitate corresponds to 0.1 per cent. KCl, if the K is to be calculated as such.

For the analysis of salts consisting essentially of K_2SO_4 , like kainite, dissolve 35.71 g., in which case each mg. of the platinum precipitate indicates 0.1 per cent. K_2SO_4 . When testing rich sulphate (90 to 97 per cent. K_2SO_4) it is necessary to add to the percentage thus found a correction of +0.3 per cent., but this should not be made in the case of potasso-magnesium sulphates.

3. Percentage of Sodium Chloride:—

(a) *In High-Grade Salts.*—If there is little or no sulphate present, the NaCl is calculated from the difference between the KCl found directly by gravimetric analysis and the total chlorides as found by titration with silver solution, p. 174. If there is an appreciable proportion of sulphate present, the percentage of (combined) SO_3 must be estimated, as well as that of potassium and chlorine. The barium sulphate obtained is calculated to KCl (1 part $\text{BaSO}_4 = 0.7465 \text{ K}_2\text{SO}_4 = 0.6388 \text{ KCl}$); this amount is deducted from the total quantity of K, calculated as KCl; the remaining KCl, which was present as such and must be quoted as such in the analysis, is deducted from that which is found when calculating all the Cl as KCl. The now remaining nominal amount of KCl is calculated as NaCl, 100 parts KCl being equivalent to 78.41 NaCl. The SO_3 found is calculated as K_2SO_4 .

(b) *In Low-Grade Salts* it is not usual to estimate the NaCl. If it is to be done, a complete analysis is required. KCl is estimated as above, in addition: Ca (p. 174), Mg (pp. 170 and 223), SO_3 (p. 133), insoluble matter, and moisture. SO_3 is calculated as CaSO_4 ; if there is not enough Ca present for all the SO_3 , the remainder is calculated as MgSO_4 , and after that as K_2SO_4 . If more Mg is present than is required to saturate the SO_3 at disposal, the remaining Mg is calculated as MgCl_2 . Any excess of Cl over that required to form KCl and MgCl_2 is calculated as NaCl.

4. *Magnesium Chloride.*—In order to distinguish the carnallite salts (which give up the MgCl_2 to alcohol) from the non-carnallitic

salts (which do not do this), shake 10 g. of the crude salt for ten minutes in a $\frac{1}{2}$ -litre flask with 100 c.c. 96 per cent. alcohol and titrate 10 c.c. of the filtrate with $\frac{1}{10}$ normal silver solution. Such salts as contain upwards of 6 per cent. Cl soluble in alcohol are regarded as belonging to the carnallite group.

5. *Total Magnesium*.—Boil 10 g. of finely ground, crude salt with 300 c.c. of water in a $\frac{1}{2}$ -litre flask for an hour; after cooling add 50 c.c. twice-normal sodium hydroxide solution, in the case of much lime being present also 20 c.c. of a 10 per cent. solution of neutral potassium oxalate, fill the flask up to the mark, filter after a quarter of an hour, and titrate 50 c.c. of the filtrate by normal hydrochloric acid. Each c.c. of the twice-normal alkali used up is = 0.04032 g. MgCl_2 . To the percentage of MgO 0.2 per cent. should be added (Precht, *Z. anal. Chem.*, 1879, p. 438).

B.—Commercial Potassium Chloride.

Weigh out 7.640 g. and proceed exactly as described under A, 2 (a), p. 221. The calculation is also made in the same manner.

Potassium chloride made from vinasses contains much sulphate and a little carbonate, which is estimated alkalimetrically.

Cyanide is sometimes present in commercial potassium chloride, occasionally in appreciable quantity.

C.—Potassium Sulphate.

Proceed just as in the case of sodium sulphate, p. 176. The potassium must sometimes be estimated, which is done as on p. 221 for A, 2 (b).

D.—Beet Ashes.

For this material special methods have been worked out by Heyer (*Chemiker-Zeitung*, 1891, pp. 1489 *et seq.*), and by Alberti and Hempel (*ibid.*, p. 1623).

E.—Commercial Carbonate of Potash.

1. *Available Alkali* is titrated with normal hydrochloric acid, as on p. 190.

2. *Total Potassium* is estimated according to p. 221, A (b), so that all sulphate is converted into chloride. Of course, initially, more hydrochloric acid must be employed in order to decompose the carbonate.

3. *Chloride* is estimated by decinormal silver solution, p. 174. 1 c.c. of this = 0.007456 g. KCl.

4. *Sulphate* is estimated as BaSO_4 , p. 134. 1 g. BaSO_4 = 0.7465 K_2SO_4 .

5. *Insoluble matter*, as on p. 190.

6. *Silicate*.—Saturate the salt with hydrochloric acid, evaporate to dryness, moisten with HCl, evaporate again, dissolve in dilute HCl, filter, wash, and strongly ignite the SiO_2 . This test is only made exceptionally, and the potassium silicate is calculated together with the carbonate.

7. *Phosphate* is estimated by the magnesia method, and is treated like the silicate.

8. *Calculation of the Analyses*.—Calculate :—

(a) K_2CO_3 from the difference between the total potassium and that corresponding to the Cl and SO_3 found.

(b) Na_2CO_3 from the difference between the total available alkali and the K_2CO_3 as calculated in (a).

(c) KCl and

(d) K_2SO_4 as above.

(e) Water and

(f) Insoluble matter, if necessary also iron, by a special test.

1. SPECIFIC GRAVITIES OF SOLUTIONS OF POTASSIUM CARBONATE AT 15°.

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. K_2CO_3 . | 1 cb.m. contains kg. K_2CO_3 . |
|-------------------|-------------------|----------------|-----------------------|----------------------------------|
| 1·000 | 0 | 0 | 0 | 0 |
| 1·005 | 1 | 0·7 | 0·50 | 5·0 |
| 1·010 | 2 | 1·4 | 1·04 | 10·50 |
| 1·015 | 3 | 2·1 | 1·60 | 16·24 |
| 1·020 | 4 | 2·7 | 2·10 | 21·42 |
| 1·025 | 5 | 3·4 | 2·64 | 27·06 |
| 1·030 | 6 | 4·1 | 3·21 | 33·06 |
| 1·035 | 7 | 4·7 | 3·77 | 39·02 |
| 1·040 | 8 | 5·4 | 4·34 | 45·14 |
| 1·045 | 9 | 6·0 | 4·90 | 51·21 |
| 1·050 | 10 | 6·7 | 5·47 | 57·44 |
| 1·055 | 11 | 7·4 | 6·00 | 63·30 |
| 1·060 | 12 | 8·0 | 6·50 | 68·90 |
| 1·065 | 13 | 8·7 | 7·07 | 75·30 |
| 1·070 | 14 | 9·4 | 7·60 | 81·32 |
| 1·075 | 15 | 10·0 | 8·10 | 87·08 |
| 1·080 | 16 | 10·6 | 8·67 | 93·64 |
| 1·085 | 17 | 11·2 | 9·20 | 99·82 |
| 1·090 | 18 | 11·9 | 9·70 | 105·73 |
| 1·095 | 19 | 12·4 | 10·20 | 111·69 |
| 1·100 | 20 | 13·0 | 10·70 | 117·70 |
| 1·105 | 21 | 13·6 | 11·26 | 124·42 |
| 1·110 | 22 | 14·2 | 11·80 | 130·98 |
| 1·115 | 23 | 14·9 | 12·30 | 137·15 |
| 1·120 | 24 | 15·4 | 12·80 | 143·36 |
| 1·125 | 25 | 16·0 | 13·30 | 149·63 |
| 1·130 | 26 | 16·5 | 13·80 | 155·94 |
| 1·135 | 27 | 17·0 | 14·30 | 162·31 |
| 1·140 | 28 | 17·7 | 14·80 | 168·72 |
| 1·145 | 29 | 18·3 | 15·30 | 175·19 |
| 1·150 | 30 | 18·8 | 15·80 | 181·70 |
| 1·155 | 31 | 19·3 | 16·30 | 188·27 |
| 1·160 | 32 | 19·8 | 16·80 | 194·88 |
| 1·165 | 33 | 20·3 | 17·30 | 201·55 |
| 1·170 | 34 | 20·9 | 17·80 | 208·26 |
| 1·175 | 35 | 21·4 | 18·30 | 215·03 |
| 1·180 | 36 | 22·0 | 18·80 | 221·84 |
| 1·185 | 37 | 22·5 | 19·26 | 228·23 |

SPECIFIC GRAVITIES OF SOLUTIONS OF POTASSIUM
CARBONATE AT 15°—*Continued.*

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. K_2CO_3 . | 1 cb.m. contains kg. K_2CO_3 . |
|-------------------|-------------------|----------------|-----------------------|----------------------------------|
| 1.190 | 38 | 23.0 | 19.70 | 234.43 |
| 1.195 | 39 | 23.5 | 20.20 | 241.39 |
| 1.200 | 40 | 24.0 | 20.70 | 248.40 |
| 1.205 | 41 | 24.5 | 21.15 | 254.86 |
| 1.210 | 42 | 25.0 | 21.60 | 261.36 |
| 1.215 | 43 | 25.5 | 22.05 | 267.91 |
| 1.220 | 44 | 26.0 | 22.50 | 274.50 |
| 1.225 | 45 | 26.4 | 22.96 | 281.26 |
| 1.230 | 46 | 26.9 | 23.41 | 287.94 |
| 1.235 | 47 | 27.4 | 23.90 | 295.17 |
| 1.240 | 48 | 27.9 | 24.40 | 302.56 |
| 1.245 | 49 | 28.4 | 24.86 | 309.51 |
| 1.250 | 50 | 28.8 | 25.32 | 316.50 |
| 1.255 | 51 | 29.3 | 25.80 | 323.79 |
| 1.260 | 52 | 29.7 | 26.30 | 331.38 |
| 1.265 | 53 | 30.2 | 26.77 | 338.64 |
| 1.270 | 54 | 30.6 | 27.17 | 345.06 |
| 1.275 | 55 | 31.1 | 27.60 | 351.90 |
| 1.280 | 56 | 31.5 | 28.05 | 359.04 |
| 1.285 | 57 | 32.0 | 28.50 | 366.23 |
| 1.290 | 58 | 32.4 | 28.96 | 373.58 |
| 1.295 | 59 | 32.8 | 29.42 | 380.99 |
| 1.300 | 60 | 33.3 | 29.97 | 389.61 |
| 1.305 | 61 | 33.7 | 30.43 | 397.11 |
| 1.310 | 62 | 34.2 | 30.86 | 404.27 |
| 1.315 | 63 | 34.6 | 31.24 | 410.81 |
| 1.320 | 64 | 35.0 | 31.60 | 417.12 |
| 1.325 | 65 | 35.4 | 32.06 | 424.80 |
| 1.330 | 66 | 35.8 | 32.52 | 432.52 |
| 1.335 | 67 | 36.2 | 32.96 | 440.02 |
| 1.340 | 68 | 36.6 | 33.38 | 447.29 |
| 1.345 | 69 | 37.0 | 33.80 | 454.61 |
| 1.350 | 70 | 37.4 | 34.22 | 461.97 |
| 1.355 | 71 | 37.8 | 34.64 | 469.37 |
| 1.360 | 72 | 38.2 | 35.06 | 476.82 |
| 1.365 | 73 | 38.6 | 35.48 | 484.30 |
| 1.370 | 74 | 39.0 | 35.90 | 491.83 |

**SPECIFIC GRAVITIES OF SOLUTIONS OF POTASSIUM
CARBONATE AT 15°—Continued.**

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | Per cent. K_2CO_3 . | 1 cb.m. contains kg. K_2CO_3 . |
|-------------------|-------------------|----------------|-----------------------|----------------------------------|
| 1·375 | 75 | 39·4 | 36·32 | 499·40 |
| 1·380 | 76 | 39·8 | 36·74 | 507·01 |
| 1·385 | 77 | 40·1 | 37·17 | 514·80 |
| 1·390 | 78 | 40·5 | 37·60 | 522·64 |
| 1·395 | 79 | 40·8 | 38·02 | 530·38 |
| 1·400 | 80 | 41·2 | 38·45 | 538·30 |
| 1·405 | 81 | 41·6 | 38·88 | 546·26 |
| 1·410 | 82 | 42·0 | 39·30 | 554·13 |
| 1·415 | 83 | 42·3 | 39·73 | 562·19 |
| 1·420 | 84 | 42·7 | 40·16 | 570·27 |
| 1·425 | 85 | 43·1 | 40·59 | 578·41 |
| 1·430 | 86 | 43·4 | 41·02 | 586·59 |
| 1·435 | 87 | 43·8 | 41·45 | 594·81 |
| 1·440 | 88 | 44·1 | 41·88 | 602·64 |
| 1·445 | 89 | 44·4 | 42·22 | 610·08 |
| 1·450 | 90 | 44·8 | 42·58 | 617·41 |
| 1·455 | 91 | 45·1 | 42·97 | 625·21 |
| 1·460 | 92 | 45·4 | 43·37 | 633·20 |
| 1·465 | 93 | 45·8 | 43·77 | 641·23 |
| 1·470 | 94 | 46·1 | 44·17 | 649·30 |
| 1·475 | 95 | 46·4 | 44·57 | 657·41 |
| 1·480 | 96 | 46·8 | 44·96 | 665·41 |
| 1·485 | 97 | 47·1 | 45·38 | 673·89 |
| 1·490 | 98 | 47·4 | 45·81 | 682·57 |
| 1·495 | 99 | 47·8 | 46·24 | 691·29 |
| 1·500 | 100 | 48·1 | 46·66 | 699·90 |
| 1·505 | 101 | 48·4 | 47·03 | 707·80 |
| 1·510 | 102 | 48·7 | 47·40 | 715·74 |
| 1·515 | 103 | 49·0 | 47·78 | 723·87 |
| 1·520 | 104 | 49·4 | 48·15 | 731·88 |
| 1·525 | 105 | 49·7 | 48·53 | 740·08 |
| 1·530 | 106 | 50·0 | 48·90 | 748·17 |
| 1·535 | 107 | 50·3 | 49·26 | 756·14 |
| 1·540 | 108 | 50·6 | 49·61 | 763·99 |
| 1·545 | 109 | 50·9 | 49·96 | 771·88 |
| 1·550 | 110 | 51·2 | 50·33 | 780·12 |
| 1·555 | 111 | 51·5 | 50·70 | 788·39 |
| 1·560 | 112 | 51·8 | 51·07 | 796·69 |
| 1·565 | 113 | 52·1 | 51·45 | 805·19 |

2. INFLUENCE OF TEMPERATURE ON THE SPECIFIC

| 0° C. | 5°. | 10°. | 15°. | 20°. | 25°. | 30°. | 35°. | 40°. | 45°. | 50°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1.588 | 1.586 | 1.583 | 1.580 | 1.577 | 1.574 | 1.571 | 1.568 | 1.566 | 1.563 | 1.559 |
| 1.577 | 1.575 | 1.573 | 1.570 | 1.568 | 1.565 | 1.563 | 1.560 | 1.557 | 1.554 | 1.551 |
| 1.567 | 1.565 | 1.563 | 1.560 | 1.558 | 1.555 | 1.553 | 1.550 | 1.548 | 1.545 | 1.543 |
| 1.557 | 1.554 | 1.552 | 1.550 | 1.548 | 1.546 | 1.544 | 1.541 | 1.538 | 1.536 | 1.533 |
| 1.547 | 1.544 | 1.542 | 1.540 | 1.538 | 1.536 | 1.534 | 1.531 | 1.528 | 1.526 | 1.523 |
| 1.536 | 1.534 | 1.532 | 1.530 | 1.528 | 1.526 | 1.524 | 1.521 | 1.518 | 1.515 | 1.512 |
| 1.526 | 1.524 | 1.522 | 1.520 | 1.518 | 1.516 | 1.514 | 1.511 | 1.508 | 1.505 | 1.502 |
| 1.516 | 1.514 | 1.512 | 1.510 | 1.508 | 1.506 | 1.503 | 1.500 | 1.498 | 1.495 | 1.492 |
| 1.506 | 1.504 | 1.502 | 1.500 | 1.498 | 1.496 | 1.493 | 1.490 | 1.488 | 1.485 | 1.482 |
| 1.496 | 1.494 | 1.492 | 1.490 | 1.488 | 1.486 | 1.484 | 1.481 | 1.478 | 1.475 | 1.472 |
| 1.486 | 1.484 | 1.482 | 1.480 | 1.478 | 1.476 | 1.474 | 1.471 | 1.468 | 1.465 | 1.462 |
| 1.476 | 1.474 | 1.472 | 1.470 | 1.468 | 1.466 | 1.464 | 1.461 | 1.458 | 1.455 | 1.452 |
| 1.466 | 1.464 | 1.462 | 1.460 | 1.458 | 1.456 | 1.454 | 1.451 | 1.448 | 1.445 | 1.442 |
| 1.456 | 1.454 | 1.452 | 1.450 | 1.448 | 1.446 | 1.444 | 1.441 | 1.438 | 1.435 | 1.432 |
| 1.446 | 1.444 | 1.442 | 1.440 | 1.438 | 1.436 | 1.434 | 1.431 | 1.428 | 1.425 | 1.422 |
| 1.436 | 1.434 | 1.432 | 1.430 | 1.428 | 1.426 | 1.424 | 1.420 | 1.418 | 1.414 | 1.411 |
| 1.426 | 1.424 | 1.422 | 1.420 | 1.418 | 1.416 | 1.414 | 1.410 | 1.408 | 1.404 | 1.401 |
| 1.416 | 1.414 | 1.412 | 1.410 | 1.408 | 1.406 | 1.404 | 1.401 | 1.398 | 1.395 | 1.392 |
| 1.406 | 1.404 | 1.402 | 1.400 | 1.398 | 1.396 | 1.394 | 1.391 | 1.388 | 1.385 | 1.382 |
| 1.396 | 1.394 | 1.392 | 1.390 | 1.388 | 1.386 | 1.384 | 1.381 | 1.378 | 1.376 | 1.373 |
| 1.386 | 1.384 | 1.382 | 1.380 | 1.378 | 1.376 | 1.374 | 1.371 | 1.368 | 1.366 | 1.363 |
| 1.376 | 1.374 | 1.372 | 1.370 | 1.368 | 1.366 | 1.364 | 1.361 | 1.358 | 1.356 | 1.353 |
| 1.366 | 1.364 | 1.362 | 1.360 | 1.358 | 1.356 | 1.354 | 1.351 | 1.348 | 1.346 | 1.343 |
| 1.356 | 1.354 | 1.352 | 1.350 | 1.348 | 1.346 | 1.344 | 1.341 | 1.338 | 1.336 | 1.333 |
| 1.346 | 1.344 | 1.342 | 1.340 | 1.338 | 1.336 | 1.334 | 1.331 | 1.328 | 1.326 | 1.323 |
| 1.336 | 1.334 | 1.332 | 1.330 | 1.328 | 1.326 | 1.324 | 1.321 | 1.318 | 1.316 | 1.313 |
| 1.326 | 1.324 | 1.322 | 1.320 | 1.318 | 1.316 | 1.314 | 1.311 | 1.308 | 1.306 | 1.303 |
| 1.316 | 1.314 | 1.312 | 1.310 | 1.308 | 1.306 | 1.303 | 1.300 | 1.298 | 1.295 | 1.292 |
| 1.306 | 1.304 | 1.302 | 1.300 | 1.298 | 1.296 | 1.293 | 1.290 | 1.288 | 1.285 | 1.282 |
| 1.296 | 1.294 | 1.292 | 1.290 | 1.288 | 1.286 | 1.283 | 1.280 | 1.278 | 1.275 | 1.273 |
| 1.286 | 1.284 | 1.282 | 1.280 | 1.278 | 1.276 | 1.273 | 1.270 | 1.268 | 1.265 | 1.263 |
| 1.276 | 1.274 | 1.272 | 1.270 | 1.268 | 1.266 | 1.263 | 1.260 | 1.257 | 1.255 | 1.252 |
| 1.266 | 1.264 | 1.262 | 1.260 | 1.258 | 1.256 | 1.253 | 1.250 | 1.247 | 1.245 | 1.242 |
| 1.256 | 1.254 | 1.252 | 1.250 | 1.248 | 1.246 | 1.243 | 1.240 | 1.238 | 1.235 | 1.232 |
| 1.246 | 1.244 | 1.242 | 1.240 | 1.238 | 1.236 | 1.233 | 1.230 | 1.228 | 1.225 | 1.222 |
| 1.236 | 1.234 | 1.232 | 1.230 | 1.228 | 1.226 | 1.224 | 1.222 | 1.219 | 1.217 | 1.214 |
| 1.226 | 1.224 | 1.222 | 1.220 | 1.218 | 1.216 | 1.214 | 1.212 | 1.209 | 1.207 | 1.204 |
| 1.216 | 1.214 | 1.212 | 1.210 | 1.208 | 1.206 | 1.204 | 1.202 | 1.199 | 1.197 | 1.194 |
| 1.206 | 1.204 | 1.202 | 1.200 | 1.198 | 1.196 | 1.194 | 1.192 | 1.189 | 1.187 | 1.184 |
| 1.196 | 1.194 | 1.192 | 1.190 | 1.188 | 1.186 | 1.184 | 1.182 | 1.179 | 1.177 | 1.174 |
| 1.186 | 1.184 | 1.182 | 1.180 | 1.178 | 1.176 | 1.174 | 1.172 | 1.170 | 1.167 | 1.164 |
| 1.176 | 1.173 | 1.171 | 1.170 | 1.168 | 1.166 | 1.164 | 1.162 | 1.160 | 1.157 | 1.155 |
| 1.166 | 1.163 | 1.161 | 1.160 | 1.158 | 1.156 | 1.154 | 1.152 | 1.150 | 1.147 | 1.145 |
| 1.156 | 1.153 | 1.151 | 1.150 | 1.148 | 1.146 | 1.144 | 1.142 | 1.140 | 1.137 | 1.135 |
| 1.144 | 1.143 | 1.141 | 1.140 | 1.138 | 1.136 | 1.134 | 1.132 | 1.130 | 1.127 | 1.125 |
| 1.133 | 1.132 | 1.131 | 1.130 | 1.128 | 1.126 | 1.124 | 1.122 | 1.120 | 1.117 | 1.114 |
| 1.123 | 1.122 | 1.121 | 1.120 | 1.118 | 1.116 | 1.114 | 1.112 | 1.110 | 1.107 | 1.104 |
| 1.113 | 1.112 | 1.111 | 1.110 | 1.108 | 1.106 | 1.104 | 1.102 | 1.100 | 1.097 | 1.094 |
| 1.103 | 1.102 | 1.101 | 1.100 | 1.098 | 1.096 | 1.094 | 1.092 | 1.090 | 1.087 | 1.084 |
| 1.093 | 1.092 | 1.091 | 1.090 | 1.089 | 1.087 | 1.086 | 1.083 | 1.081 | 1.079 | 1.077 |
| 1.083 | 1.082 | 1.081 | 1.080 | 1.079 | 1.077 | 1.076 | 1.073 | 1.071 | 1.069 | 1.067 |
| 1.073 | 1.072 | 1.071 | 1.070 | 1.069 | 1.067 | 1.066 | 1.064 | 1.062 | 1.060 | 1.058 |
| 1.063 | 1.062 | 1.061 | 1.060 | 1.059 | 1.057 | 1.056 | 1.054 | 1.052 | 1.050 | 1.048 |
| 1.053 | 1.052 | 1.051 | 1.050 | 1.049 | 1.047 | 1.046 | 1.044 | 1.042 | 1.040 | 1.038 |
| 1.043 | 1.042 | 1.041 | 1.040 | 1.039 | 1.037 | 1.036 | 1.034 | 1.032 | 1.030 | 1.028 |
| 1.033 | 1.032 | 1.031 | 1.030 | 1.028 | 1.027 | 1.025 | 1.024 | 1.022 | 1.020 | 1.018 |
| 1.023 | 1.022 | 1.021 | 1.020 | 1.018 | 1.017 | 1.015 | 1.014 | 1.012 | 1.010 | 1.008 |
| 1.013 | 1.012 | 1.011 | 1.010 | 1.008 | 1.007 | 1.005 | 1.004 | 1.002 | 1.000 | 0.998 |

GRAVITIES OF SOLUTIONS OF POTASSIUM CARBONATE.

| 55°. | 60°. | 65°. | 70°. | 75°. | 80°. | 85°. | 90°. | 95°. | 100°. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1·556 | 1·553 | 1·550 | 1·546 | 1·542 | 1·538 | 1·534 | 1·530 | 1·526 | 1·521 |
| 1·548 | 1·545 | 1·541 | 1·537 | 1·533 | 1·530 | 1·526 | 1·522 | 1·518 | 1·513 |
| 1·539 | 1·536 | 1·532 | 1·528 | 1·525 | 1·522 | 1·517 | 1·513 | 1·509 | 1·505 |
| 1·530 | 1·527 | 1·524 | 1·521 | 1·517 | 1·513 | 1·509 | 1·504 | 1·501 | 1·498 |
| 1·520 | 1·517 | 1·514 | 1·511 | 1·508 | 1·504 | 1·500 | 1·497 | 1·494 | 1·490 |
| 1·509 | 1·507 | 1·504 | 1·500 | 1·497 | 1·494 | 1·491 | 1·488 | 1·485 | 1·481 |
| 1·499 | 1·497 | 1·494 | 1·490 | 1·487 | 1·484 | 1·481 | 1·478 | 1·475 | 1·471 |
| 1·489 | 1·487 | 1·484 | 1·480 | 1·477 | 1·474 | 1·471 | 1·468 | 1·465 | 1·461 |
| 1·479 | 1·476 | 1·474 | 1·470 | 1·467 | 1·464 | 1·461 | 1·458 | 1·455 | 1·451 |
| 1·469 | 1·466 | 1·464 | 1·460 | 1·457 | 1·454 | 1·450 | 1·447 | 1·444 | 1·441 |
| 1·459 | 1·456 | 1·454 | 1·450 | 1·447 | 1·444 | 1·440 | 1·437 | 1·434 | 1·431 |
| 1·449 | 1·446 | 1·444 | 1·440 | 1·437 | 1·434 | 1·431 | 1·428 | 1·424 | 1·421 |
| 1·439 | 1·436 | 1·434 | 1·430 | 1·427 | 1·424 | 1·421 | 1·418 | 1·414 | 1·411 |
| 1·429 | 1·426 | 1·423 | 1·420 | 1·417 | 1·414 | 1·410 | 1·408 | 1·405 | 1·402 |
| 1·419 | 1·416 | 1·413 | 1·410 | 1·407 | 1·404 | 1·400 | 1·398 | 1·396 | 1·392 |
| 1·409 | 1·406 | 1·401 | 1·401 | 1·398 | 1·395 | 1·391 | 1·388 | 1·385 | 1·382 |
| 1·399 | 1·396 | 1·394 | 1·391 | 1·388 | 1·385 | 1·381 | 1·378 | 1·375 | 1·372 |
| 1·390 | 1·387 | 1·384 | 1·380 | 1·377 | 1·374 | 1·371 | 1·368 | 1·365 | 1·362 |
| 1·380 | 1·377 | 1·374 | 1·370 | 1·367 | 1·364 | 1·361 | 1·358 | 1·355 | 1·352 |
| 1·370 | 1·367 | 1·364 | 1·361 | 1·358 | 1·355 | 1·351 | 1·348 | 1·345 | 1·342 |
| 1·360 | 1·357 | 1·354 | 1·351 | 1·348 | 1·345 | 1·341 | 1·338 | 1·335 | 1·332 |
| 1·350 | 1·347 | 1·344 | 1·341 | 1·338 | 1·335 | 1·332 | 1·329 | 1·326 | 1·323 |
| 1·340 | 1·337 | 1·334 | 1·331 | 1·328 | 1·325 | 1·322 | 1·319 | 1·316 | 1·313 |
| 1·330 | 1·327 | 1·324 | 1·321 | 1·318 | 1·315 | 1·312 | 1·309 | 1·306 | 1·303 |
| 1·320 | 1·317 | 1·314 | 1·311 | 1·308 | 1·305 | 1·302 | 1·299 | 1·296 | 1·293 |
| 1·310 | 1·307 | 1·304 | 1·301 | 1·298 | 1·295 | 1·292 | 1·289 | 1·286 | 1·283 |
| 1·300 | 1·297 | 1·294 | 1·291 | 1·288 | 1·285 | 1·282 | 1·279 | 1·276 | 1·274 |
| 1·290 | 1·287 | 1·284 | 1·281 | 1·278 | 1·276 | 1·273 | 1·270 | 1·267 | 1·264 |
| 1·280 | 1·277 | 1·274 | 1·271 | 1·268 | 1·266 | 1·263 | 1·260 | 1·257 | 1·254 |
| 1·270 | 1·267 | 1·264 | 1·261 | 1·258 | 1·256 | 1·253 | 1·250 | 1·247 | 1·244 |
| 1·260 | 1·257 | 1·254 | 1·251 | 1·248 | 1·246 | 1·243 | 1·240 | 1·237 | 1·234 |
| 1·250 | 1·247 | 1·244 | 1·242 | 1·239 | 1·236 | 1·234 | 1·231 | 1·228 | 1·225 |
| 1·240 | 1·237 | 1·234 | 1·232 | 1·229 | 1·226 | 1·224 | 1·221 | 1·218 | 1·215 |
| 1·230 | 1·227 | 1·224 | 1·221 | 1·218 | 1·216 | 1·213 | 1·210 | 1·208 | 1·205 |
| 1·220 | 1·217 | 1·214 | 1·211 | 1·208 | 1·206 | 1·203 | 1·200 | 1·198 | 1·195 |
| 1·212 | 1·209 | 1·205 | 1·202 | 1·198 | 1·196 | 1·194 | 1·192 | 1·188 | 1·186 |
| 1·202 | 1·199 | 1·196 | 1·193 | 1·190 | 1·187 | 1·184 | 1·182 | 1·178 | 1·176 |
| 1·192 | 1·189 | 1·186 | 1·183 | 1·180 | 1·178 | 1·175 | 1·172 | 1·169 | 1·167 |
| 1·182 | 1·179 | 1·176 | 1·173 | 1·171 | 1·168 | 1·165 | 1·162 | 1·159 | 1·157 |
| 1·172 | 1·169 | 1·166 | 1·164 | 1·161 | 1·158 | 1·155 | 1·152 | 1·149 | 1·146 |
| 1·162 | 1·159 | 1·156 | 1·154 | 1·151 | 1·148 | 1·145 | 1·142 | 1·139 | 1·136 |
| 1·152 | 1·150 | 1·147 | 1·144 | 1·141 | 1·138 | 1·135 | 1·132 | 1·129 | 1·126 |
| 1·142 | 1·140 | 1·137 | 1·134 | 1·131 | 1·128 | 1·125 | 1·122 | 1·119 | 1·116 |
| 1·132 | 1·130 | 1·128 | 1·125 | 1·122 | 1·118 | 1·115 | 1·112 | 1·109 | 1·106 |
| 1·122 | 1·120 | 1·118 | 1·115 | 1·112 | 1·108 | 1·105 | 1·102 | 1·099 | 1·096 |
| 1·112 | 1·110 | 1·108 | 1·105 | 1·102 | 1·098 | 1·095 | 1·092 | 1·089 | 1·086 |
| 1·102 | 1·100 | 1·098 | 1·095 | 1·092 | 1·088 | 1·085 | 1·082 | 1·078 | 1·076 |
| 1·092 | 1·090 | 1·087 | 1·084 | 1·082 | 1·079 | 1·075 | 1·072 | 1·069 | 1·067 |
| 1·082 | 1·080 | 1·077 | 1·074 | 1·072 | 1·069 | 1·065 | 1·062 | 1·059 | 1·057 |
| 1·074 | 1·071 | 1·068 | 1·065 | 1·063 | 1·060 | 1·057 | 1·054 | 1·050 | 1·048 |
| 1·066 | 1·062 | 1·059 | 1·056 | 1·054 | 1·051 | 1·048 | 1·045 | 1·041 | 1·038 |
| 1·056 | 1·053 | 1·050 | 1·047 | 1·045 | 1·042 | 1·039 | 1·036 | 1·032 | 1·029 |
| 1·046 | 1·044 | 1·041 | 1·038 | 1·036 | 1·033 | 1·030 | 1·026 | 1·023 | 1·020 |
| 1·036 | 1·033 | 1·031 | 1·028 | 1·025 | 1·022 | 1·019 | 1·016 | 1·013 | 1·010 |
| 1·026 | 1·023 | 1·021 | 1·018 | 1·015 | 1·012 | 1·009 | 1·006 | 1·003 | 1·000 |
| 1·016 | 1·014 | 1·012 | 1·009 | 1·006 | 1·002 | 0·999 | 0·996 | 0·993 | 0·990 |
| 1·007 | 1·004 | 1·002 | 0·999 | 0·996 | 0·993 | 0·990 | 0·987 | 0·984 | 0·981 |
| 0·996 | 0·994 | 0·992 | 0·989 | 0·986 | 0·983 | 0·980 | 0·977 | 0·974 | 0·971 |

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**8. SPECIFIC GRAVITY OF SOLUTIONS OF POTASSIUM
HYDROXIDE AT 15°
 4° . Calculated from the results
obtained by Pickering (*Journ. Chem. Soc.*, lxiii., 890).**

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | 100 parts by weight contain | | 1 cb.m. contains kg. | |
|-------------------|-------------------|----------------|-----------------------------|-------|----------------------|--------|
| | | | K ₂ O. | KOH. | K ₂ O. | KOH. |
| 1·000 | 0 | 0 | 0·00 | 0·00 | 0·00 | 0·00 |
| 1·005 | 1 | 0·7 | 0·50 | 0·60 | 5·03 | 6·03 |
| 1·010 | 2 | 1·4 | 0·99 | 1·18 | 10·00 | 11·92 |
| 1·015 | 3 | 2·1 | 1·45 | 1·73 | 14·72 | 17·56 |
| 1·020 | 4 | 2·7 | 1·91 | 2·28 | 19·48 | 23·20 |
| 1·025 | 5 | 3·4 | 2·37 | 2·82 | 24·29 | 28·91 |
| 1·030 | 6 | 4·1 | 2·82 | 3·36 | 29·05 | 34·61 |
| 1·035 | 7 | 4·7 | 3·27 | 3·90 | 33·84 | 40·37 |
| 1·040 | 8 | 5·4 | 3·73 | 4·44 | 38·79 | 46·18 |
| 1·045 | 9 | 6·0 | 4·19 | 4·99 | 43·79 | 52·15 |
| 1·050 | 10 | 6·7 | 4·64 | 5·53 | 48·72 | 58·07 |
| 1·055 | 11 | 7·4 | 5·10 | 6·08 | 53·81 | 64·14 |
| 1·060 | 12 | 8·0 | 5·54 | 6·60 | 58·72 | 69·96 |
| 1·065 | 13 | 8·7 | 6·00 | 7·15 | 63·90 | 76·15 |
| 1·070 | 14 | 9·4 | 6·45 | 7·68 | 69·02 | 82·18 |
| 1·075 | 15 | 10·0 | 6·90 | 8·22 | 74·18 | 88·37 |
| 1·080 | 16 | 10·6 | 7·35 | 8·76 | 79·38 | 94·61 |
| 1·085 | 17 | 11·2 | 7·79 | 9·28 | 84·52 | 100·69 |
| 1·090 | 18 | 11·9 | 8·24 | 9·82 | 89·82 | 107·04 |
| 1·095 | 19 | 12·4 | 8·68 | 10·37 | 95·05 | 113·22 |
| 1·100 | 20 | 13·0 | 9·13 | 10·87 | 100·43 | 119·57 |
| 1·105 | 21 | 13·6 | 9·62 | 11·46 | 106·30 | 126·63 |
| 1·110 | 22 | 14·2 | 10·00 | 11·92 | 110·00 | 132·31 |
| 1·115 | 23 | 14·9 | 10·44 | 12·44 | 116·41 | 138·71 |
| 1·120 | 24 | 15·4 | 10·88 | 12·96 | 121·86 | 145·15 |
| 1·125 | 25 | 16·0 | 11·32 | 13·48 | 127·35 | 151·65 |
| 1·130 | 26 | 16·5 | 11·76 | 14·01 | 132·89 | 158·31 |
| 1·135 | 27 | 17·0 | 12·21 | 14·53 | 138·58 | 164·92 |
| 1·140 | 28 | 17·7 | 12·63 | 15·04 | 143·98 | 171·46 |
| 1·145 | 29 | 18·3 | 13·06 | 15·56 | 149·53 | 178·16 |
| 1·150 | 30 | 18·8 | 13·50 | 16·08 | 155·25 | 184·92 |
| 1·155 | 31 | 19·3 | 13·92 | 16·58 | 160·78 | 191·50 |
| 1·160 | 32 | 19·8 | 14·36 | 17·10 | 166·58 | 198·36 |
| 1·165 | 33 | 20·3 | 14·79 | 17·62 | 172·30 | 205·27 |
| 1·170 | 34 | 20·9 | 15·22 | 18·13 | 178·07 | 212·12 |
| 1·175 | 35 | 21·4 | 15·65 | 18·64 | 183·89 | 219·02 |

SPECIFIC GRAVITY OF SOLUTIONS OF POTASSIUM

HYDROXIDE AT $\frac{15^{\circ}}{4^{\circ}}$ —Continued.

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | 100 parts by weight contain | | 1 cb.m. contains kg. | |
|-------------------|-------------------|----------------|-----------------------------|-------|----------------------|--------|
| | | | K ₂ O. | KOH. | K ₂ O. | KOH. |
| 1·180 | 36 | 22·0 | 16·08 | 19·15 | 189·74 | 225·97 |
| 1·185 | 37 | 22·5 | 16·51 | 19·66 | 195·64 | 232·97 |
| 1·190 | 38 | 23·0 | 16·93 | 20·17 | 201·47 | 240·02 |
| 1·195 | 39 | 23·5 | 17·35 | 20·66 | 207·33 | 246·89 |
| 1·200 | 40 | 24·0 | 17·77 | 21·17 | 213·24 | 254·04 |
| 1·205 | 41 | 24·5 | 18·18 | 21·66 | 219·07 | 261·00 |
| 1·210 | 42 | 25·0 | 18·60 | 22·16 | 225·06 | 268·14 |
| 1·215 | 43 | 25·5 | 19·03 | 22·67 | 231·21 | 275·44 |
| 1·220 | 44 | 26·0 | 19·45 | 23·17 | 237·29 | 282·67 |
| 1·225 | 45 | 26·4 | 19·86 | 23·66 | 243·29 | 289·84 |
| 1·230 | 46 | 26·9 | 20·27 | 24·14 | 249·32 | 296·92 |
| 1·235 | 47 | 27·4 | 20·69 | 24·64 | 255·52 | 304·30 |
| 1·240 | 48 | 27·9 | 21·10 | 25·13 | 261·64 | 311·61 |
| 1·245 | 49 | 28·4 | 21·51 | 25·62 | 267·80 | 318·97 |
| 1·250 | 50 | 28·8 | 21·91 | 26·10 | 273·88 | 326·25 |
| 1·255 | 51 | 29·3 | 22·32 | 26·59 | 280·12 | 333·70 |
| 1·260 | 52 | 29·7 | 22·73 | 27·07 | 286·40 | 341·08 |
| 1·265 | 53 | 30·2 | 23·14 | 27·56 | 292·72 | 348·63 |
| 1·270 | 54 | 30·6 | 23·54 | 28·04 | 298·96 | 356·11 |
| 1·275 | 55 | 31·1 | 23·94 | 28·52 | 305·24 | 363·63 |
| 1·280 | 56 | 31·5 | 24·35 | 29·00 | 311·68 | 371·20 |
| 1·285 | 57 | 32·0 | 24·75 | 29·48 | 318·04 | 378·82 |
| 1·290 | 58 | 32·4 | 25·15 | 29·96 | 324·44 | 386·48 |
| 1·295 | 59 | 32·8 | 25·55 | 30·43 | 330·87 | 394·07 |
| 1·300 | 60 | 33·3 | 25·95 | 30·91 | 337·35 | 401·83 |
| 1·305 | 61 | 33·7 | 26·34 | 31·37 | 343·74 | 409·38 |
| 1·310 | 62 | 34·2 | 26·73 | 31·84 | 350·16 | 417·10 |
| 1·315 | 63 | 34·6 | 27·13 | 32·31 | 356·76 | 424·88 |
| 1·320 | 64 | 35·0 | 27·52 | 32·78 | 363·26 | 432·70 |
| 1·325 | 65 | 35·4 | 27·91 | 33·24 | 369·81 | 440·43 |
| 1·330 | 66 | 35·8 | 28·29 | 33·70 | 376·26 | 448·21 |
| 1·335 | 67 | 36·2 | 28·68 | 34·16 | 382·88 | 456·04 |
| 1·240 | 68 | 36·6 | 29·07 | 34·63 | 389·54 | 464·04 |
| 1·345 | 69 | 37·0 | 29·46 | 35·09 | 396·24 | 471·96 |
| 1·350 | 70 | 37·4 | 29·85 | 35·55 | 402·98 | 479·93 |
| 1·355 | 71 | 37·8 | 30·23 | 36·01 | 409·62 | 487·94 |
| 1·360 | 72 | 38·2 | 30·61 | 36·46 | 416·30 | 495·86 |

SPECIFIC GRAVITY OF SOLUTIONS OF POTASSIUM

HYDROXIDE AT $\frac{15^\circ}{4^\circ}$ —Continued.

| Specific Gravity. | Degrees Twaddell. | Degrees Baumé. | 100 parts by weight contain | | 1 cb.m. contains kg. | |
|-------------------|-------------------|----------------|-----------------------------|-------|----------------------|--------|
| | | | K ₂ O. | KOH. | K ₂ O. | KOH. |
| 1.365 | 73 | 38.6 | 30.99 | 36.92 | 423.01 | 503.96 |
| 1.370 | 74 | 39.0 | 31.37 | 37.37 | 429.77 | 511.97 |
| 1.375 | 75 | 39.4 | 31.76 | 37.83 | 436.70 | 520.16 |
| 1.380 | 76 | 39.8 | 32.14 | 38.28 | 443.53 | 528.26 |
| 1.385 | 77 | 40.1 | 32.52 | 38.73 | 450.40 | 536.41 |
| 1.390 | 78 | 40.5 | 32.89 | 39.18 | 457.17 | 544.60 |
| 1.395 | 79 | 40.8 | 33.27 | 39.63 | 464.12 | 552.84 |
| 1.400 | 80 | 41.2 | 33.66 | 40.09 | 471.24 | 561.26 |
| 1.405 | 81 | 41.6 | 34.03 | 40.53 | 478.12 | 569.45 |
| 1.410 | 82 | 42.0 | 34.40 | 40.98 | 485.04 | 577.82 |
| 1.415 | 83 | 42.3 | 34.77 | 41.42 | 492.00 | 586.09 |
| 1.420 | 84 | 42.7 | 35.15 | 41.87 | 499.13 | 594.55 |
| 1.425 | 85 | 43.1 | 35.53 | 42.32 | 506.30 | 603.06 |
| 1.430 | 86 | 43.4 | 35.90 | 42.76 | 513.37 | 611.47 |
| 1.435 | 87 | 43.8 | 36.27 | 43.20 | 520.47 | 619.92 |
| 1.440 | 88 | 44.1 | 36.63 | 43.63 | 527.47 | 628.27 |
| 1.445 | 89 | 44.4 | 36.99 | 44.06 | 534.51 | 636.67 |
| 1.450 | 90 | 44.8 | 37.36 | 44.50 | 541.72 | 645.25 |
| 1.455 | 91 | 45.1 | 37.72 | 44.93 | 548.83 | 653.73 |
| 1.460 | 92 | 45.4 | 38.09 | 45.37 | 556.11 | 662.40 |
| 1.465 | 93 | 45.8 | 38.45 | 45.80 | 563.29 | 670.97 |
| 1.470 | 94 | 46.1 | 38.81 | 46.23 | 570.51 | 679.58 |
| 1.475 | 95 | 46.4 | 39.17 | 46.66 | 577.76 | 688.24 |
| 1.480 | 96 | 46.8 | 39.54 | 47.09 | 585.19 | 696.93 |
| 1.485 | 97 | 47.1 | 39.89 | 47.51 | 592.37 | 705.52 |
| 1.490 | 98 | 47.4 | 40.24 | 47.93 | 599.58 | 714.16 |
| 1.495 | 99 | 47.8 | 40.60 | 48.36 | 606.97 | 722.98 |
| 1.500 | 100 | 48.1 | 40.95 | 48.78 | 614.25 | 731.70 |
| 1.505 | 101 | 48.4 | 41.31 | 49.20 | 621.72 | 740.46 |
| 1.510 | 102 | 48.7 | 41.68 | 49.61 | 629.37 | 749.56 |
| 1.515 | 103 | 49.0 | 42.03 | 50.06 | 636.75 | 758.41 |
| 1.520 | 104 | 49.4 | 42.38 | 50.48 | 644.18 | 767.30 |
| 1.525 | 105 | 49.7 | 42.73 | 50.90 | 651.63 | 776.23 |
| 1.530 | 106 | 50.0 | 43.09 | 51.32 | 659.28 | 785.20 |
| 1.535 | 107 | 50.3 | 43.44 | 51.74 | 666.80 | 794.21 |
| 1.540 | 108 | 50.6 | 43.78 | 52.15 | 674.21 | 803.11 |

XIII. AMMONIA MANUFACTURE.

A.—Gas-Liquor.

This liquor generally contains the ammonia principally in the state of carbonate and sulphide, which can be driven off by boiling, without employing lime or alkali, and which are indicated by alkalimetric testing (*volatile ammonia*). There is, however, always a certain quantity of ammonia present in the state of salts which are not appreciably volatilised by mere boiling, and not indicated by simple testing with standard acid. These are the chloride, thiocyanate, sulphite, thiosulphate, sulphate, ferrocyanide (*fixed ammonia*). No other salts need be enumerated.

For technical purposes, it is sufficient to make the following tests:—

1. *Volatile Ammonia*.—Direct titration of the liquor gives inaccurate results.

Dilute 25 c.c. of the liquor to 350 c.c. and distil from a round-bottom flask through a Leibig condenser into a tube containing excess of $\frac{N}{2}$ H_2SO_4 . The tube should be packed with fragments of hard glass (not beads as these often yield alkali). Distil until 200 c.c. has passed over and titrate back the acid with standard alkali.

2. *Fixed Ammonia*.—The residue in the flask is then made up to about the original volume; excess of sodium hydroxide added and the ammonia distilled again as above into a measured amount of standard acid. The ammonia is determined as before by finding the amount of acid used by back titration with standard alkali.

3. *Carbonic Acid*.—Fifty c.c. of the liquor are added to an excess of an ammoniacal solution of calcium chloride and heated for two hours on the water-bath. After cooling, the precipitate is filtered through a Gooch crucible, washed three or four times with warm water, dissolved in standard hydrochloric acid and back titrated with standard alkali.

4. *Total Sulphur*.—Run 50 c.c. of gas-liquor, drop by drop, into bromine, covered by hydrochloric acid, evaporate to dryness on the water-bath, and precipitate the sulphuric acid formed by barium chloride, as described, p. 134.

Sometimes it may be desirable to deduct from the total sulphur that originally present in the gas-liquor as sulphate, which is estimated by boiling the unoxidised gas-liquor with HCl and proceeding as above.

5. *Thiocyanate*.—Evaporate 50 c.c. of gas-liquor to dryness, heat the residue at 100°C ., for three or four hours, digest it with strong alcohol, filter, wash on the filter with alcohol, evaporate all the alcoholic solutions to dryness, dissolve in water, filter from any residue, add a mixed solution of sulphurous acid and cupric sulphate, and heat gently, when cuprous thiocyanate will be precipitated. Wash the precipitate of CuCNS into a flask, dissolve it in nitric acid, boil for some time, and precipitate the Cu as CuO by NaOH . The weight of $\text{CuO} \times 0.9561 =$ the equivalent amount of $(\text{NH}_4)\text{CNS}$ (Dyson, *S.C.I.*, 1883, p. 231). Or else proceed by titration, employing a solution containing

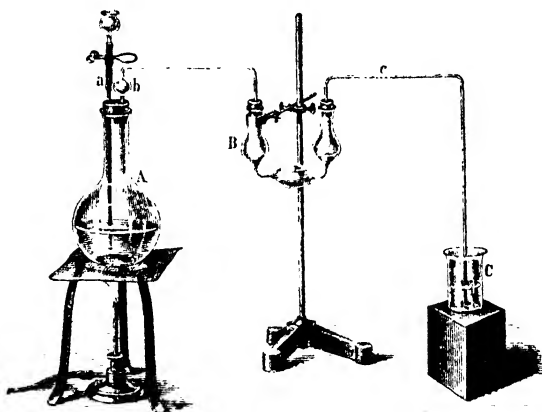


FIG. 18.

6.236 g. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ per litre, 1 c.c. of which is equivalent to 0.00145 g. $\text{SCN} = 0.00190 \text{ g. } (\text{NH}_4)\text{SCN}$, which is added to a boiling solution, to which some sodium bisulphite has been added, till a drop of the mixture, brought into contact with a drop of a solution of potassium ferrocyanide in 20 parts of water, produces *immediately* a brown coloration (Barnes and Liddell, *S.C.I.*, 1883, p. 122).

B.—Sulphate of Ammonia.

1. *Estimation of Ammonia*.—The average sample, carefully drawn, is well ground up, passed completely through a sieve with 10 holes to the linear inch, and a smaller sample is taken from this. Weigh 17.03 g. of the latter sample in a stoppered tube, dissolve and dilute to 500 c.c., and place 50 c.c. of the solution

without filtration into the apparatus, Fig. 18 (p. 234). The test is carried out exactly as in A, No. 2. As absorbent, use 60 c.c. of $\frac{N}{2}$ H_2SO_4 and when the distillation is complete, find the number of c.c. of $\frac{N}{2}$ $\text{NaOH} = a$ c.c. required to complete the neutralisation of the sulphuric acid. Each c.c. of the quantity

$$\frac{60 - a}{2} \text{ is } = 0.01703 \text{ g. NH}_3 \text{ or } = 1.0 \text{ per cent.}$$

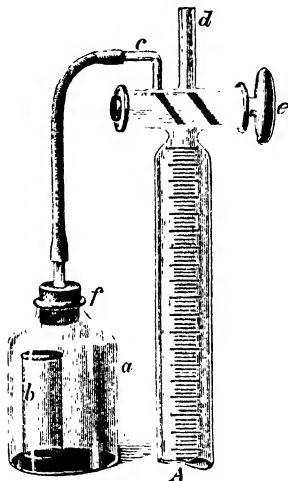


FIG. 19.

The analysis of sulphate of ammonia is, however, best, and much more quickly performed by the bromine method, in which the NH_3 is converted into nitrogen. This method can be carried out in the "Azotometer." The necessary "brominated soda" is prepared by dissolving 100 g. 70 per cent. caustic soda in 1250 g. water, and cautiously adding 25 g. bromine. The reagent must be kept in a dark, cool place, but even then does not keep more than a few days. The ammonium salt, preferably dissolved in water, is introduced into the outer space of the decomposing flask *a*, Fig. 19, and 25 or 30 c.c. brominated soda poured into the inner vessel *b*. The cork *f*, having been already attached to the volumeter-tube by means of a short rubber tube, is pressed tightly down into the flask *a*, taking hold of this only by the neck; the pressure thus produced

is relieved by momentarily pulling out the stopper of the volumeter-tap *e*. If thereby the mercury in A should sink a little, it is brought back to the zero point by raising the "level-tube," while A communicates through *d* with the outer air. When the temperatures are equalised and the mercury is up to the tap, this is put in such a position that *a* communicates through *c* with A; then the flask *a* is tilted so that the contents of *b* run into the outer space; the flask is then shaken till no more gas is evolved. The mercury levels in A and the level-tube are made to coincide, after waiting a quarter of an hour, or, better, half an hour, in order to cool down the flask. (This may be expedited by placing *a* both before and after the operation, in a large vessel filled with water of the temperature of the room.) When the levels have been exactly adjusted, as described p. 188, so as to bring the gas to the volume it would occupy at 0° and 760 mm. in the dry state, read off the number of c.c. of gas in A; each c.c. = 0.0012818 g. N = 0.0015582 g. NH_3 (this includes the necessary correction for absorption or incomplete evolution of N). In order to save all calculations, dissolve 1.558 g. sulphate of ammonia in 100 c.c. of water, and employ 10 c.c. = 0.1558 g. for each test; in this case each c.c. of gas contained in A = 1 per cent. NH_3 .

2. *Thiocyanate*.—*Cf.* p. 143, A, No. 4.

3. *Free Acid* is found by titration with decinormal soda solution and methyl orange.

4. *Moisture* is estimated by drying 50 g. in a stove at 100° up to constancy of weight.

C.—Ammonia (Liquor Ammoniaë).

This is mostly sold by specific gravity, the relation of which to the percentage of NH_3 is shown in the subjoined table No. 1.

The *empyreumatic* substances in liquor ammoniaë are detected qualitatively by the smell on exact neutralisation with sulphuric acid. The *pyridine bases* (which do not redden phenolphthalein) can be tested for by the method of Pennock and Morton (*Journ. Amer. Chem. Soc.*, vol. xxiv., p. 377). Neutralise 100 c.c. of the liquor exactly by sulphuric acid, employing methyl orange as indicator and cooling the vessel used from the outside; distil into a flask charged with 30 c.c. water until this volume has increased to about 100 c.c., add phenolphthalein and a solution of mercuric chloride until the liquid is decolorised, then a few more drops of the mercury solution (thereby precipitating the NH_3), filter, and titrate with decinormal acid and methyl orange, each c.c. of which = 0.0079 g. pyridine.

The testing of *liquid ammonia*, as sent out in iron bottles, is described in *Tech. Meth.*

1. SPECIFIC GRAVITIES OF SOLUTIONS OF AMMONIA AT 60° F. (Price and Hawkins, *J.S.C.I. Trans.*, 1924, 48, 113.)

| Specific gravity. | Per cent. NH_3 . | Specific gravity. | Per cent. NH_3 . |
|-------------------|---------------------------|-------------------|---------------------------|
| 0.875 | 36.90 | 0.938 | 16.25 |
| 0.876 | 36.56 | 0.940 | 15.65 |
| 0.877 | 36.22 | 0.942 | 15.06 |
| 0.878 | 35.88 | 0.944 | 14.47 |
| 0.880 | 35.20 | 0.946 | 13.89 |
| 0.882 | 34.53 | 0.948 | 13.31 |
| 0.884 | 33.86 | 0.950 | 12.74 |
| 0.886 | 33.19 | 0.952 | 12.17 |
| 0.888 | 32.52 | 0.954 | 11.61 |
| 0.890 | 31.85 | 0.956 | 11.05 |
| 0.892 | 31.18 | 0.958 | 10.50 |
| 0.894 | 30.51 | 0.960 | 9.95 |
| 0.896 | 29.84 | 0.962 | 9.40 |
| 0.898 | 29.17 | 0.964 | 8.86 |
| 0.900 | 28.50 | 0.966 | 8.32 |
| 0.902 | 27.83 | 0.968 | 7.79 |
| 0.904 | 27.16 | 0.970 | 7.27 |
| 0.906 | 26.49 | 0.972 | 6.75 |
| 0.908 | 25.82 | 0.974 | 6.24 |
| 0.910 | 25.15 | 0.976 | 5.73 |
| 0.912 | 24.48 | 0.978 | 5.23 |
| 0.914 | 23.82 | 0.980 | 4.73 |
| 0.916 | 23.16 | 0.982 | 4.24 |
| 0.918 | 22.50 | 0.984 | 3.75 |
| 0.920 | 21.85 | 0.986 | 3.27 |
| 0.922 | 21.21 | 0.988 | 2.79 |
| 0.924 | 20.57 | 0.990 | 2.31 |
| 0.926 | 19.94 | 0.992 | 1.84 |
| 0.928 | 19.31 | 0.994 | 1.37 |
| 0.930 | 18.69 | 0.996 | 0.91 |
| 0.932 | 18.07 | 0.998 | 0.45 |
| 0.934 | 17.46 | 1.000 | 0.00 |
| 0.936 | 16.85 | ... | ... |

See also Ferguson, *J. Soc. Chem. Ind.*, 1905, 781, for table adopted by the Manufacturing Chemists' Association of the United States.

2. SPECIFIC GRAVITIES OF SOLUTIONS OF COMMERCIAL AMMONIUM CARBONATE, AT 15° C. (Lunge and Smith.)

| Degrees Twaddell. | Degrees Baumé. | Specific Gravity at 15°. | Per cent. Commercial Ammonium Carbonate. | Change of Specific Gravity for $\pm 1^\circ \text{C}$. |
|-------------------|----------------|--------------------------|--|---|
| 1 | 0.6 | 1.005 | 1.66 | 0.0002 |
| 2 | 1.4 | 1.010 | 3.18 | 0.0002 |
| 3 | 2.1 | 1.015 | 4.60 | 0.0003 |
| 4 | 2.7 | 1.020 | 6.04 | 0.0003 |
| 5 | 3.4 | 1.025 | 7.49 | 0.0003 |
| 6 | 4.1 | 1.030 | 8.93 | 0.0004 |
| 7 | 4.7 | 1.035 | 10.35 | 0.0004 |
| 8 | 5.4 | 1.040 | 11.86 | 0.0004 |
| 9 | 6.0 | 1.045 | 13.36 | 0.0005 |
| 10 | 6.7 | 1.050 | 14.83 | 0.0005 |
| 11 | 7.4 | 1.055 | 16.16 | 0.0005 |
| 12 | 8.0 | 1.060 | 17.70 | 0.0005 |
| 13 | 8.7 | 1.065 | 19.18 | 0.0005 |
| 14 | 9.4 | 1.070 | 20.70 | 0.0005 |
| 15 | 10.0 | 1.075 | 22.25 | 0.0006 |
| 16 | 10.6 | 1.080 | 23.78 | 0.0006 |
| 17 | 11.2 | 1.085 | 25.31 | 0.0007 |
| 18 | 11.9 | 1.090 | 26.82 | 0.0007 |
| 19 | 12.4 | 1.095 | 28.33 | 0.0007 |
| 20 | 13.0 | 1.100 | 29.93 | 0.0007 |
| 21 | 13.6 | 1.105 | 31.77 | 0.0007 |
| 22 | 14.2 | 1.110 | 33.45 | 0.0007 |
| 23 | 14.9 | 1.115 | 35.08 | 0.0007 |
| 24 | 15.4 | 1.120 | 36.88 | 0.0007 |
| 25 | 16.0 | 1.125 | 38.71 | 0.0007 |
| 26 | 16.5 | 1.130 | 40.34 | 0.0007 |
| 27 | 17.1 | 1.135 | 42.20 | 0.0007 |
| 28 | 17.8 | 1.140 | 44.29 | 0.0007 |
| 29 | 17.9 | 1.1414 | 44.90 | 0.0007 |

**XIV. MANUFACTURE OF COAL-GAS
(ILLUMINATING GAS).**

A.—Coal-Gas.

For a satisfactory analysis of coal-gas the Orsat apparatus (p. 120) is not sufficiently accurate, and the gas-burettes of Bunte, Hempel, Drehschmidt, or Pfeiffer should be used. The following rules are taken from the private notes, printed for Professor Bunte's students, with his permission.

The analysis is performed by means of Bunte burettes, which must satisfy the following conditions :—The capillary tube below the bottom tap must not allow any water to come out, even on shaking. The upper (three-way) tap must be made so as to shut off communication with any one of the three outlets. (The Greiner-Friedrichs patent tap, with two oblique bores, as shown in Fig. 19, p. 235, admits of doing this without any difficulty.) The taps should be greased with a mixture of 2 parts para-gum, 2 parts bees-wax, and 10 parts tallow, and they must be tight even in a strong vacuum. The confining water must have the temperature of the room, and this must remain unchanged during the whole time occupied by the work. The burette must be held only at the top funnel or at the capillary tubes. The correctness of its graduation must be controlled by running out its contents of water in portions of 10 c.c., and weighing these. When one of the components of the gas has been absorbed, first allow the water to rise from below and then adjust the pressure by allowing water to run in from the top funnel. To do this, fill it to the mark, open the tap and wait a minute, until the surface of the water inside the burette remains constant.

To take a sample of the gas to be tested, employ either an empty burette, or one filled with water. In the former case, connect the top tap (the funnel being charged with water) sideways with the gasholder or pipe, the bottom tap being open, and allow the gas to pass through, until it has driven out all the air; then shut first the bottom tap and immediately afterwards the top tap. In the second case fill the burette with water, connect the top tap with the gasholder or pipe, open the bottom tap, until the water has sunk a little below the zero mark, then shut first the top tap and afterwards the bottom tap.

If the gas is at a lower pressure than the atmospheric pressure, take the sample by means of a rubber bellows, or a water aspirating bottle, or a water-pump, and connect then with the bottom capillary.

Measuring the gas in the burette.—Adjust the three-way tap so that all its bores are closed, fill the funnel with water up to the mark, connect the rubber tube of the pressure bottle (levelling bottle), previously entirely filled with water, with the bottom tap, and allow the water to rise up to about 0.2 c.c. above the zero mark. Now open the three-way tap, whereupon a little gas escapes and the pressures are equalised. The water then usually stands at the zero mark; if not, read the actual volume and calculate from this. Then turn the three-way tap, after having put a short rubber tube on its lateral outlet, so as to run a little water into this, and close the tube by a small piece of glass rod. As long as the tap is not used, it remains in this position.

Introduction of the absorbing liquids.—Draw off the confining liquid by means of the aspirating bottle, holding the bottom tap

fast in its position, and shutting it at once when the water has got down to the capillary. Take the rubber tube off and draw the liquid back into the aspirating bottle, lest it should siphon itself off. Then pour the absorbing liquid into a small porcelain capsule, and allow it to rise in the burette.

The various gases are estimated, *seriatim*, as follows :—

1. *Carbon Dioxide*, CO_2 , by absorption with a solution of caustic potash, 1 in 3 water—that is, specific gravity 1.23. Of this 1 c.c. takes up 90-100 c.c. CO_2 . It is sufficient, if the inside of the burette is once wetted with the solution. Afterwards water is allowed to enter from below and to run in from the top, to wash the glass; then the normal pressure is re-established and the volume read off. In the case of crude gas the H_2S must be first removed by a tube containing pumice soaked with cupric sulphate.

2. *Heavy hydrocarbons*, C_mH_n .—Draw out the confining water as completely as possible, rinse off the potash solution with a little water (which is also drawn off), allow about 10 c.c. of water, saturated with bromine, to enter, and shake the burette. When the space above the liquid ceases to show the brown colour of the bromine, draw off the liquid and replace it by fresh bromine water. Finally, in order to absorb the bromine vapour, draw about 1 c.c. of caustic potash solution into the burette, shake this up in the burette, allow a little water to run in at the top, establish the normal pressure, and read off the volume. Thus all the illuminants are absorbed—*i.e.*, ethylene and the other unsaturated hydrocarbons, also benzene vapour.

3. *Oxygen* is absorbed by drawing in about 2.5 c.c. of a solution of pyrogallol (1 to 5 water) and after this 7.5 c.c. caustic potash solution (1 : 3). Shake well for five minutes, run in water through the funnel until the pressure is equalised, shake again, and continue this until no more water will enter the burette. Run off the dark liquid at the bottom, allowing water to run in at the top, so that a layer of clear water remains at the top, which allows a correct reading after re-establishing the pressure.

Accurate estimations of oxygen are made by titration with potassium iodide, manganous chloride, and thiosulphate, as described in *Tech. Meth.*, vol. i, pp. 209 and 334.

4. *Carbon Monoxide*.—Draw off the confining water, wash with more water, draw in 10 c.c. ammoniacal solution of cuprous chloride (made by dissolving 200 g. commercial cuprous chloride and 250 g. ammonium chloride in 750 c.c. water, placing a copper spiral in the bottle, and before use mixing 3 vols. of this solution with 1 vol. ammonia, specific gravity 0.905), shake for one minute, draw off the solution, replace it by a fresh quantity, shake again, and repeat this procedure at least twice. After the last removal of the absorbent, run through the funnel 3 or 4 c.c. concentrated

hydrochloric acid, and then a little water, which forms a layer at the top. Draw off the liquid, wash with water, draw in 1 or 2 c.c. concentrated potash solution, shake up, allow some water to enter, re-establish the normal pressure, and take the reading.

5. *Hydrogen*.—The gas now contains nothing but H , CH_4 , and N . The hydrogen is estimated by fractional combustion, for which purpose a second burette (B) is needed. Measure in the first burette (A) 22 to 25 c.c. of the residual gas under normal pressure, and mix with air for burning the hydrogen. For this purpose open first the bottom tap, then the top tap, so as to communicate outwards, whereupon water will run out and air enter. When the level of the water has gone down to about 5 c.c. below 0, quickly shut the top tap and after this the bottom tap, mix the gases by shaking, regulate the pressure to that of the atmosphere plus that of the column of water in the funnel, and read the volume. Now fill burette B up to the capillary and connect both three-way taps, interposing a *palladium tube* C, between them. C is a tube of glass of high melting point, 10 cm. long, 3 mm. bore, and 5 mm. thick. It contains a 100 mm. of palladium wire, 0.3 mm. thick, folded into four and introduced into the central part of tube C. By heating this part of the tube, it is made to collapse and to hold the wire fast; the remaining portion of C is loosely filled with long fibrous asbestos. The connection between C and the capillaries of A and B is made by short, thick-walled rubber tubing.

Now turn both three-way taps so that both are closed, fill the funnel of burette A with water, lower the pressure by opening the bottom tap for a moment, turn both three-way taps at the same time and quickly, so that C communicates with the interior of both burettes, and heat C. The air in C thus increases its volume, and forces the water in the capillaries back into both burettes. Now connect the rubber tube of the pressure bottle with the lower tap of A, open this tap, heat C at its narrowed part until the small flame turns yellow, and open the lower tap of B, so that the gas passes from A through C into B in a moderately quick current. The water should issue from B in a continuous jet, not in single drops, and the palladium wire should not become red-hot on the side where the gas enters; otherwise some methane would be burnt together with the hydrogen. As soon as the water has got to the top of the burette A, quickly shut first the bottom tap of A and then that of B, and syphon the gas back from B to A as described above. After cooling, the pressure in A is made equal to the normal; the volume is then read, and the contraction ascertained.

Example: 100 c.c. coal-gas, taken for analysis, after absorbing CO_2 , heavy hydrocarbons, O and CO, left 85 c.c. Of this 22.2 c.c. were transferred to burette A, and diluted with air to 105.3. After the combustion the volume was 86.3, showing a contraction

of 19.0. Calculating this upon a 100 c.c. of the original gas, we find

$$\frac{19.0 \times 85.0}{22.2} = 72.8.$$

Therefore the hydrogen amounts to $\frac{2 \times 72.8}{3} = 48.5$ per cent.

As a final control, estimate the *oxygen* left after combustion ; it must be less than that originally employed by two-thirds of the contraction observed.

6. *Methane* is estimated, together with hydrogen, by burning another portion of the gas remaining after the operations 1 to 4, in the "explosion burette." For this, measure off 12 to 15 c.c. of this gas, draw in an excess of air, shake up, ascertain the volume, draw off the confining water, explode by means of an electric spark (generated by a battery and induction coil), ascertain the contraction, let 1 or 2 c.c. potash solution run down inside the burette, and after this, slowly, some water, adjust the pressure and ascertain the total contraction, which is equal to $\text{H}_2\text{O} + \text{CO}_2$. From this deduct the amount corresponding to the hydrogen found in No. 5 ; one-third of the remaining contraction corresponds to the methane, for 1 vol. $\text{CH}_4 + 2$ vols. $\text{O}_2 = 0$ vols. $\text{CO}_2 + 0$ vols. H_2O .

Example : Residual gas employed, 12.7 c.c. (forming part of the 86 c.c. remaining after the absorption of CO_2 , C_mH_n , O_2 , and CO) ; after addition of air = 104.1 ; therefore air employed = 91.4. After the explosion remain 78.9 c.c. gas ; therefore contraction = 25.2 ; calculated upon the total gas $\frac{85 \times 25.5}{12.7} = 168.8$. From this

deduct the contraction due to hydrogen, according to No. 5, = 72.8 ; this leaves for the methane a contraction of $168.8 - 72.8 = 96.0$, or one-third of it = 32.0 per cent. methane.

7. *Nitrogen* is represented by the deficit from 100 after estimating all the other constituents. Suppose we have found :—

| | | | |
|-------------|------|-----------|----------------------|
| From No. 1, | 2.0 | per cent. | (by volume) CO |
| " " | 2, | 4.0 | " heavy hydrocarbons |
| " " | 3, | 0.4 | " O_2 |
| " " | 4, | 8.6 | " CO |
| <hr/> | | | |
| Together | 15.0 | " | |
| From No. 5, | 48.0 | " | H_2 |
| " " | 6, | 32.0 | " CH_4 |
| <hr/> | | | |
| | 95.0 | " | |
| Leaving | 5.0 | " | for N_2 |

The estimation of ethylene, benzene, acetylene, naphthalene, hydrogen sulphide, total sulphur, ammonia, cyanogen, etc., is described in Lunge-Keane's *Tech. Meth. of Chem. Anal.*, vol. ii.

The calorific power of coal-gas is best ascertained by means of the Junckers calorimeter, which is always sold with instructions for use.

B.—Purifying Material (Spent Oxide).

1. *Cyanogen* (Bueb).—Boil 20 g. of an average sample of spent oxide (from which the sulphur has been previously extracted as below), or the same quantity of pressed "cyanide mud," with 100 c.c. caustic potash solution (specific gravity 1.26) and 200 c.c. water for half an hour, dilute to 1010 c.c. (reckoning 10 c.c. for the volume of the solid substance), and pass through a dry filter. Take 25 c.c. of the filtrate, add 50 c.c. water and 10 c.c. dilute sulphuric acid (1 : 10), and titrate with *zinc solution*. This solution is made as follows:—Dissolve 10.2 g. of pure crystallised zinc sulphate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$), together with 10 c.c. sulphuric acid of specific gravity 1.7 in water, make up to 1 litre, and compare this with a freshly made solution of 10 g. pure crystallised potassium ferrocyanide in 1 litre, in the following manner:—To 25 c.c. of the ferrocyanide solution add 50 c.c. water and 10 c.c. dilute sulphuric acid. This mixture is titrated with the zinc solution, testing for the completion of the reaction by drops put on to filter paper soaked with a 1 per cent. solution of ferric chloride. The end of the reaction is reached when no blue coloration is produced on the paper.

Other methods for the estimation of cyanides (described by Knublauch and by Drehschmidt) are given in *Tech. Meth.*, vol. i., pp. 546 *et seq.*, and vol. ii., p. 725.

2. *Sulphur*.—Extract 15 g. of the air-dried mass in a Soxhlet apparatus with 100 c.c. carbon disulphide in a 200 c.c. round-bottomed flask of known weight. Heat on a water-bath, condensing the vapours by a reflux condenser, until twenty extractions have been made. Distil off the CS_2 , remove the last portions by hot air, and after cooling again weigh the flask. The difference between the weighings = S.

Sometimes it is desirable to know the amount of S which on burning the oxide forms SO_2 , since a certain quantity of S is always retained by lime, etc., on burning the spent mass. For this purpose Pfeiffer burns 1 g. of the sample, by putting a piece of tinder in a litre flask filled with oxygen and previously charged with 25 or 30 c.c. of normal caustic soda solution. Finally he adds 1 c.c. neutral 30 per cent. hydrogen peroxide and titrates back with standard HCl and methyl orange. Each c.c. of the normal soda solution consumed corresponds to 1.6 per cent. of S burnt.

Processes for estimating all the essential constituents of spent oxide are described in *Tech. Meth.*, vol. ii., pp. 723 to 730.

XV. CALCIUM CARBIDE AND ACETYLENE.

A.—Raw Materials.

- (a) *Coke*, see p. 117.
 (b) *Limestone*, see p. 183.

B.—Commercial Calcium Carbide.

(a) *The sampling* in this case has to be done with special care, since it is anything but easy to obtain a small sample representing the real average quality. The sample is quickly crushed in an iron mortar, provided with a rubber cover, or in a coffee-mill, and the powder must be kept free from contact with air.

(b) *The estimation of the yield of gas* should always be made by actual measurement of the gas, not by loss of weight. Take 50 g. carbide, and put it into a glass tube, 2 or 3 cm. wide inside, which is connected with the gas-generating flask (250 c.c.) by a rubber tube so that the carbide can be dropped in small quantities into the flask. 150 c.c. water, previously saturated with acetylene, are first placed in the flask, the cork of which is also provided with an exit-tube connected with a measuring bottle. This bottle holds 20 litres, and has a division on which $\frac{1}{2}$ litre can be read off. It is connected by means of a lateral neck just over the bottom and by a rubber tube with a level-bottle of the same size, filled with water saturated with acetylene. By raising the level-flask, the water is forced into the measuring flask up to its neck; during the time the gas is given off, the level flask is lowered, so that there is never any notable pressure in the measuring bottle. When all the gas has been collected in the latter, the level-bottle is placed so that the water is exactly at the same level in both bottles, and about two hours are allowed for the temperature to reach that of the surrounding air. Read the thermometer and barometer, and reduce the volume of the gas by the tables, pp. 12 *et seq.*, to the normal state, regarding it as saturated with moisture. If, as usual, the reduction is to be made not to 0°, but to 15° C., this can be done with sufficient accuracy by the formula :—

$$V = \frac{v}{100} (140 \cdot 2 - 0 \cdot 6 t) \frac{B}{100}$$

where V is the volume at 15°, *v* the volume at *t*°, and B the (corrected height) of the barometer. (*Cf. Tech. Meth.*)

(c) *Impurities*.—It is best to test for these, not in the carbide, but in the acetylene given off from it. Put 70 or 80 g. carbide, crushed to the size of a pea, into a previously weighed, well-dried, half-litre flask, and weigh it on an ordinary balance which turns to 0.1 g. The cork of this flask is fitted with a dropping funnel,

contracted at the outlet, with glass tap, and with a side tube connected with a ten-bulb tube, like that shown in Fig. 10, p. 144. The latter contains 75 c.c. of a 2 to 3 per cent. solution of sodium hypochlorite. Run from the funnel three to seven drops of water on to the carbide, and shake the flask gently from time to time. The gas should all be liberated in three or four hours; it may, if required, be measured, or else allowed to escape. Then the flask is filled up to its neck, so as to drive all the gas into the bulb-tube, and in the contents of the latter the phosphoric acid which has been formed by the hypochlorite from the *hydrogen phosphide* contained in the gas, is estimated by the ordinary magnesia method.

If it is required to estimate the *sulphur* also, which escapes principally as H_2S , divide the contents of the bulb-tube in two portions, estimate in one of these the phosphoric acid as above, and in the other the sulphuric acid, formed from the H_2S , as BaSO_4 .

XVI. EXAMINATION OF THE RAW MATERIALS AND PRODUCTS OF THE MANUFACTURE OF FERTILISERS.

Note.—This section is based on the resolutions agreed to at the Fifth International Congress of Applied Chemistry at Berlin (1903).

A.—Sampling.

Samples must be taken out of every tenth sack in the case of shipments in bulk, in at least ten places, by means of the sampling-auger described on p. 105; in the case of ship cargoes, from every fiftieth tub; the total weight to be about 300 g. for each of the three normal samples. In the case of unequal composition, the samples must be ground and mixed; in the case of moist fertilisers, this must be done by hand.

B.—Moisture.

Moisture in crude phosphates, bone charcoal, etc., is estimated by drying 10 g. at 100° until weight is constant; in the case of gypsum, during three hours. If the substance alters its percentage of moisture during grinding, the moisture must be determined both in the coarsely crushed and in the finely ground sample, and the result of the analysis calculated on the original coarsely crushed sample.

C.—The Insoluble Matter.

The insoluble matter is determined in 10 g. of the sample. (a) When dissolving in mineral acids, after rendering the silica insoluble by heating on the water-bath during several hours, or on the air-bath to 120°, the residue must be ignited. (b) When dissolving in water, the residue must be dried at 100° up to constancy of weight.

D.—Phosphoric Acid.**1. Preparation of the Solutions.**

(a) *Phosphates soluble in Water*.—Shake 20 g. in a litre flask with about 800 g. water for half an hour, and fill up to the mark. Solutions of so-called double superphosphates must be boiled with addition of nitric acid (10 c.c. concentrated nitric acid to 25 c.c. of the solution) before precipitating the phosphoric acid, in order to convert any pyrophosphoric acid present into orthophosphoric acid.

(b) *Phosphates soluble in Ammonium Citrate* are treated according to Petermann's method. In the case of superphosphates containing upwards of 20 per cent. P_2O_5 , take 1 g.; of those containing 12 to 20 per cent. P_2O_5 , take 2 g.; if there is less than 10 per cent., P_2O_5 , or of a composite fertiliser, take 4 g. for each sample. Grind it first dry, then with 20 to 25 c.c. water, decant on to a filter, and wash with water until the volume of the filtrate is about 200 c.c. If the filtrate is not quite clear, add a drop of nitric acid. Put the filter and residue into a 250 c.c. flask, add 100 c.c. of the ammonium citrate solution (prepared as below), digest about fifteen hours at the ordinary temperature, with frequent shaking, then one hour at 40°, allow to cool, fill up to the mark, take 50 c.c. of the filtrate and 50 c.c. of the above aqueous solution, mix these, boil with 10 c.c. concentrated nitric acid for ten minutes, and estimate the total phosphoric acid soluble in water and in citrate by the molybdenum or the citrate method.

Preparation of the Ammonium Citrate Solution.—Dissolve 500 g. citric acid in water, neutralise with ammonia, allow to cool, reduce the specific gravity to 1.09, and add to a litre of this solution 50 c.c. ammonia, specific gravity 0.92. The specific gravity of the final solution should be from 1.082 to 1.083.

(c) *Total Phosphoric Acid*.—Boil 5 g. with a mixture of three parts hydrochloric acid (specific gravity 1.12) and 1 part nitric acid (specific gravity 1.20), or with 20 c.c. concentrated nitric acid and 50 c.c. concentrated sulphuric acid for half an hour, and make up to 250 c.c.

(d) In *Thomas-Slag Phosphates* the phosphoric acid is estimated in the portion which passes through a 2-millimetre sieve,

but the result is calculated upon the whole sample, including the coarser portion. The following estimations are made :—

1. *Phosphoric Acid soluble in Citric Acid.*—Shake 5 g. Thomas phosphate in a half-litre flask, previously charged with 5 c.c. alcohol, with a 2 per cent. solution of pure citric acid during half an hour at $17\frac{1}{2}^{\circ}$, in a revolving agitator which makes thirty to forty revolutions per minute.

2. *Total Phosphoric Acid.*—Soak 10 g. Thomas phosphate (for the analysis of fine flour passed through sieve No. 100= 0.19 mm. mesh) in a half-litre flask with 5 c.c. water, then boil with 50 c.c. concentrated sulphuric acid half an hour, stirring frequently, and fill up to the mark.

2. Examination of the Solutions.

For phosphoric acid, according to one of the following methods :—

(a) *Molybdenum Method*, according to Wagner.—To 25 or 50 c.c. solution, free from silica and containing from 0.1 to 0.2 g. P_2O_5 , add so much concentrated solution of ammonium nitrate (750 g. per litre) and so much molybdenum solution (150 g. ammonium molybdate, dissolved in 1 litre water and poured into 1 litre nitric acid of specific gravity 1.2) that the total liquid contains 15 per cent. ammonium nitrate, and for each 0.1 g. P_2O_5 , not less than 50 c.c. molybdenum solution. Heat to 80° or 90° for ten minutes, put aside for an hour, filter, wash the precipitate with dilute solution of ammonium nitrate (150 g. $(NH_4)NO_3$ + 10 c.c. nitric acid in 1 litre) until there is no reaction for calcium, pierce the filter, wash the precipitate into a beaker by means of a $2\frac{1}{2}$ per cent. ammonia, dissolve it by stirring, and add so much ammonia that the total volume is 75 c.c. Then add for each 0.1 g. P_2O_5 , 10 c.c. of magnesium mixture (55 g. crystallised magnesium chloride + 70 g. ammonium chloride, dissolved in 1 litre of 2.5 per cent. ammonia), in single drops, stirring constantly, cover the beaker, allow to stand for two hours, filter the precipitate, wash it with 2.5 per cent. ammonia until the reaction for chlorine ceases, and dry at 100° . Detach the precipitate from the filter, place it in a platinum crucible, add the rolled-up filter, and carbonise it in a covered crucible; then heat the crucible for ten minutes in an upright position over the Bunsen flame and for five minutes on the blowpipe.

(b) *Citrate Method.*—In the case of aqueous solutions of superphosphate, employ 50 c.c. citrate solution for 50 c.c. of the phosphate solution, corresponding to 1 g. substance; in that of acid solutions of bone meal, fish guano, Thomas-slag, flour, etc., take 100 c.c. of the citrate solution for 50 c.c. of the phosphate solution ($=\frac{1}{2}$ g. substance). The *citrate solution* is made by dissolving 1100 g. pure citric acid in water, adding 4 litres of 24 per cent.

ammonia, and making up to 10 litres. After adding the citrate solution, add *at once* 25 c.c. magnesium mixture (550 g. magnesium chloride + 1050 ammonium chloride, dissolved in 6½ litres water + 3½ litres 27 per cent. ammonia), and shake or stir for half an hour. Filter the precipitate, preferably by means of a Gooch or Neubauer crucible (see below), rinse the beaker with 5 per cent. ammonia, and wash the precipitate five or six times with the same solution, using a filter pump. Dry the crucible on a hot plate until the mass begins to crack, ignite for three to five minutes (preferably in a Roessler furnace), and allow to cool in a desiccator. After weighing, the crucible may at once be used for a fresh determination, without removing the precipitate, and thus thirty or forty estimations can be made in it without renewing the asbestos filter.

This method involves several errors, which, however, compensate one another, so that when the above details are strictly adhered to, the final result is perfectly correct. According to the resolutions of the Union of the German Agricultural Research Stations in 1903, the citrate method is the only one admissible for all fertilisers, except crude phosphates.

The preparation of a Gooch crucible—that is, a platinum crucible with platinum sieve and asbestos filter—is a little troublesome; it is described in *Tech. Meth.* (second edition), vol. i., p. 18.

The Neubauer crucible (sold by W. C. Heraeus, Hanau) is similar to the Gooch crucible, but contains a platinum sponge filter on the sieve. It is ready for use, as obtained from the dealers, and is much more convenient than a Gooch crucible.

E.—Free Acids.

(a) The total free acid is estimated by titration with caustic soda solution and methyl orange.

(b) Free phosphoric acid is estimated gravimetrically in the alcoholic extract, as described above.

F.—Ferric Oxide and Alumina.

In Germany the accepted method is that of E. Glaser. Dissolve 5 g. phosphate in 25 c.c. nitric acid (specific gravity 1·2) + 12·5 c.c. hydrochloric acid (specific gravity 1·12), and dilute to 500 c.c. Put 100 c.c. (= 1 g. of the phosphate) in a 250 c.c. flask, add 25 c.c. concentrated sulphuric acid (specific gravity 1·84); after five minutes' shaking add 100 c.c. 95 per cent. alcohol, allow to cool, fill up to the mark with alcohol, shake well, and fill up again. After waiting for half an hour, filter, heat 100 c.c. of the filtrate in a platinum dish until the alcohol is driven off, transfer to a beaker,

add 50 c.c. water, and heat to boiling. Remove the flame, add NH_3 till the reaction is alkaline, boil off the excess of NH_3 , allow to cool, filter, wash with hot water, ignite, and weigh. The weight found is assumed to be aluminium phosphate + ferric phosphate, or 50 per cent. of it = $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$.

G.—Nitrogen.

1. *Nitric-nitrogen* is estimated gas-volumetrically by the nitrometer (pp. 164 and 165), or by Schloesing-Grandeau's method (*Tech. Meth.*, second edition, vol. i., p. 482), or by one of the methods for reducing it to NH_3 . The following method is due to Ulsch. Into a flat-bottomed half-litre flask put 25 c.c. of the aqueous nitrate solution (which ought to contain at most 0.5 g. $\text{KNO}_3 = 0.4$ g. NaNO_3) and 10 c.c. dilute sulphuric acid (1 vol. concentrated acid + 2 vols. water), add 5 g. commercial "ferrum hydrogenio reductum" (iron reduced by hydrogen), and close the flask with a pear-shaped glass vessel of 25 c.c. capacity filled with water, which at the same time serves as a reflux condenser. Heat first cautiously, then more strongly, at least for half a minute to full boiling (altogether five minutes), dilute with 50 c.c. water, add 20 c.c. caustic soda solution (specific gravity 1.25), and distil the NH_3 formed into titrated hydrochloric or sulphuric acid. The distillation may be finished in five to seven minutes after the commencement of the boiling. By titrating back the excess of acid the quantity of NH_3 is ascertained; each c.c. normal acid saturated = 0.01401 g. N or 0.06302 HNO_3 or 0.10116 KNO_3 or 0.08506 NaNO_3 .

2. *Ammoniacal nitrogen*, cf. p. 233. Preferably distil with freshly calcined magnesia, 3 g. to 1 g. NH_3 . In the case of ammoniacal superphosphates, the solution prepared as on p. 246 should be used.

3. *Total nitrogen* is estimated in presence of nitrates by Kjeldahl-Jodlbauer's method. Place 1 g. substance in a flask of difficultly fusible glass holding about 350 c.c., slowly add 30 c.c. phenolsulphuric acid (made by dissolving 200 g. P_2O_5 in 500 c.c. concentrated sulphuric acid, and 40 g. phenol in 500 c.c. concentrated sulphuric acid, and uniting the two solutions, after cooling), shaking continuously, and cooling by placing the flask in cold water. When finished agitate for another half-hour or hour, add a drop of mercury (about 1 g.) and then gradually 2 to 3 g. dried zinc dust, with good agitation and cooling. Allow to stand for one or two hours; then boil until the solution has become clear and colourless, allow to cool, wash with water into a distilling flask, add 110 c.c. of caustic soda solution of specific gravity 1.285 (which must be free from nitrogen compounds), distil the NH_3 .

into normal hydrochloric acid, and estimate it by retitrating. The calculation is made as above, *sub* C, 1.

Damp substances are ground up with a little gypsum before adding the phenolsulphuric acid.

4. *Organic nitrogen*, in the absence of nitrates and ammonium salts, is estimated according to Kjeldahl-Wilfarth's method. Put 1 g. substance in a 150 c.c. long-necked flask of Bohemian glass, add a drop of mercury and 25 c.c. of concentrated sulphuric acid, to a litre of which 200 g. P_2O_5 and 15 g. K_2SO_4 have been added. Heat at first slowly, then to violent boiling, putting the flask, or several flasks, on a wire gauze in a slanting position. The whole is best placed on a sheet of lead with turned-up edges, covered with a thick layer of sand and placed under a hood, so that no damage is done if a flask is cracked. In the case of badly frothing liquids put a little paraffin in the flask and close this loosely by a Kreusler's stopper, *i.e.*, a glass tube drawn out below into a long point, and sealed at the bottom. Continue the boiling until the contents of the flask are quite clear, which may take half an hour to three hours. Then wash its contents by the aid of 200 c.c. water into a half-litre flask, add 100 c.c. caustic soda solution of specific gravity 1.285 (free from N) and 1 to 1.5 g. zinc dust, and distil into titrated HCl, proceeding just as in No. 1.

In the case of substances which cannot be finely ground, prepare a good average sample by weighing off 3 to 5 g., boil with 50 to 60 c.c. sulphuric acid and 2 to 3 g. mercury, wash, after cooling, into a 300 c.c. flask, filling this up to the mark, mix by shaking, and take 100 c.c. for the distillation with caustic soda and zinc dust.

H.—Potash.

Potash is estimated as in potassium chloride containing sulphate, p. 221, or by the perchloric acid method.

Details for the examination of the various fertilisers are given in *Tech. Meth.*, vol. ii., pp. 418 *et seq.*

XVII. ALUMINA PREPARATIONS.

A.—Raw Materials.

1. *Kaolin (china clay)*, see p. 254, *sub* "Clay."

2. *Bauxite (a)*—Dry 2.500 g. at 100° for eight hours, boil with 30 c.c. of a mixture of 1 part concentrated sulphuric acid + 1 water, with good agitation, until vapours of SO_3 begin to escape, allow to cool, run the paste slowly into 300 c.c. cold water so as to prevent heating (which would cause a precipitation of TiO_2), add

10 c.c. hydrochloric acid, digest six hours with agitation, filter the solution (a) from the precipitated crude silica and make it, with the washings, up to 500 c.c. Ignite the crude silica, weigh it, evaporate with 2 c.c. hydrofluoric acid and three drops of dilute sulphuric acid, and ignite; the residue is weighed as Al_2O_3 , and by deducting it from the crude silica we obtain the pure SiO_2 .

(b) Take 200 c.c. of the solution (a) (= 1.000 g. bauxite), neutralise with sodium carbonate until a slight precipitate begins to appear, bring this again into solution by adding a few drops of dilute sulphuric acid, reduce the contained iron to the ferrous state by NaHSO_3 or gaseous SO_2 , dilute to 400 or 450 c.c., boil for two hours, replacing the evaporated water by an aqueous solution of SO_2 . The *titanic acid* is thus precipitated. Allow to cool, make up to 500 c.c., pour through a dry filter and wash the TiO_2 with warm water containing a little ammonium chloride, but keep the washings separate from the first filtrate. Dry, ignite, and weigh the TiO_2 .

(c) Boil 125 c.c. of the first filtrate obtained in (b) (= 0.250 g. bauxite) till the SO_2 has been removed, add a little zinc, dilute strongly, and estimate the *iron* by titration with permanganate, after having rendered the solution slightly acid by sulphuric acid, as described p. 180.

(d) *Alumina, Ferric Oxide, and Titanic Acid* together are estimated in the first solution (a). Take 25 c.c. of this solution (= 0.125 g. bauxite), add a little fuming nitric and hydrochloric acid, dilute considerably, add NH_3 in slight excess, boil up for a moment, filter, dissolve the precipitate again in hydrochloric acid, precipitate again with NH_3 , wash, filter, dry and weigh. By adding the alumina found in (a), and deducting the TiO_2 found in (b), and the ferric oxide in (c), we obtain the remainder = *Alumina*.

(e) Ignite a fresh sample of dried bauxite for a quarter of an hour by means of the blowpipe; the loss of weight is = chemically combined water + organic matter.

B.—Control of Working Conditions.

1. The *residue* from decomposing the bauxite is tested by boiling 2 g. with 3 c.c. concentrated sulphuric acid + 3 c.c. water until the red colour is destroyed, diluting a little, filtering, and making the filtrate up to 100 c.c. In this we estimate:

(a) *Iron* in 10 c.c. by reducing it to the ferrous state and titrating with KMnO_4 , p. 180.

(b) *Ferric oxide + Alumina* by precipitation with NH_3 .

(c) *Soluble soda* by boiling 20 c.c. with a solution of ammonium chloride and absorbing the NH_3 set free in titrated hydrochloric acid.

2. *Aluminate solution*.—In this we estimate Na_2O and Al_2O_3 in the same operation, as described below for sodium aluminate.

C.—Commercial Products.**1. Sulphate of Alumina and Alum :—**

(a) *Estimation of Alumina*—(a) *Gravimetric estimation*.—Dissolve 10 g. in water, dilute to $\frac{1}{2}$ litre, take 50 c.c. of the clear solution = 1 g. of the substance, add ammonia in slight excess, boil up for a moment, filter, wash, dry the precipitate, ignite, and weigh the Al_2O_3 . It is slightly contaminated with traces of iron, silicate, and phosphoric acid, which may be neglected.

(b) *Volumetric Analysis*.—Dissolve 5 g. in water, dilute to $\frac{1}{2}$ litre, take out 50 c.c. = 0.5 g. substance, neutralise the free acid by dilute solution of caustic soda (indicator: methyl orange, till the pink changes to yellow), then add phenolphthalein and titrate with standard caustic soda solution until the red colour appears. Each c.c. of the NaOH solution corresponds to 0.1703 g. Al_2O_3 .

N.B.—This method gives only approximate results, unless a number of precautions, detailed in *Tech. Meth.*, vol. i., p. 613, are observed.

(b) *Iron* cannot be estimated either gravimetrically or by titration, on account of its small quantity. Hence it is estimated colorimetrically by Lunge and Kéler's method. We require for this a number of small stoppered cylinders of white glass, 13 mm. internal diameter, 17 cm. high, containing 25 c.c. divided in 0.1 c.c., and a free space of 5 c.c. above the 25 c.c. mark. Also the following reagents:—(1) a 10 per cent. solution of potassium thiocyanate; (2) pure ether; (3) a solution of 8.630 g. ammonium-iron-alum and 5 c.c. concentrated sulphuric acid in 1 litre; (4) a solution prepared from (3) by diluting it in the proportion of 1:100, so that this solution contains 10 mg. Fe per litre. It should be kept protected from sunlight, but even then keeps only for a few days, whereas solution (3), when protected from air and light, keeps a long time without getting turbid; (5) pure nitric acid. It is hardly possible to obtain nitric acid absolutely free from iron, but this does not matter, if it gives only a slight pink colour with potassium thiocyanate, since very little of it is used, and an equal quantity for the check test as for the actual test.

Dissolve 1 or 2 g. of the aluminium sulphate, weighed exactly, in a little water, add exactly 1 c.c. of the pure nitric acid (5), heat a few minutes, allow to cool, and dilute to 50 c.c. Put 5 c.c. of this solution into one of the colorimeter cylinders, A. (*N.B.*—If this method is applied to estimate traces of iron in sulphuric acid, this is diluted in the same way.) Into a second cylinder, B, put 5 c.c. of dilute nitric acid, obtained by diluting 1 c.c. of (5) to 50 c.c., and a certain accurately measured quantity of the iron-alum solution (3), *e.g.*, 1 c.c. Add as much pure water to cylinder A as you put iron solution in B, so as to always have the same degree of dilution in A and B. Then add to both A

and B 5 c.c. of the thiocyanate solution (1) and 10 c.c. of the ether (2), put the stopper in and shake thoroughly, until the aqueous layer has become colourless and the red colour has passed over entirely into the ether. The comparison of the colours in A and B is most accurate after a few hours, since they deepen a little on standing, but marked differences can be observed at once, so that three cylinders will suffice, of which A receives the solution to be tested, B and C the quantities of iron most nearly approaching to A. The comparison is made by holding the cylinders a little distance from a white surface (*not* putting them down upon it!) and looking at them from the top downwards. It is then quite easy to estimate differences of ± 0.1 c.c. of the iron-alum solution (5), that is of ± 0.001 mg. Fe in the 5 c.c. employed for analysis, but only when the total quantity of iron does not exceed 2 c.c. of the solution, that is ≈ 0.02 mg. Fe. If there should be more than this present, the permanganate method is applicable.

(c) *Free acid* in aluminium sulphate cannot be directly titrated by any of the hitherto known indicators. Beilstein and Grosse proceed as follows:—Dissolve 1 or 2 g. of the sulphate in 5 c.c. water, add 5 c.c. of a cold saturated solution of ammonium sulphate, stir fifteen minutes, and precipitate with 50 c.c. 95 per cent. alcohol. Wash the precipitate with 50 c.c. alcohol, evaporate the alcohol from the mixed filtrate and washings on the water-bath, and titrate the acid in the residue by decinormal soda solution and phenolphthalein.

(d) *Zinc* only occurs occasionally in commercial sulphate of alumina, but is very injurious. Estimate it by adding to the solution of the sulphate a sufficient quantity of barium acetate to precipitate all the sulphuric acid, and precipitating the zinc in the filtrate as ZnS.

2. Aluminate of Soda:—

(a) *Soda and Alumina*.—Dissolve 2 g. in water, dilute to 100 c.c. and titrate 10 c.c. (≈ 0.2 g. substance) quite hot, with phenolphthalein as indicator, by fifth normal hydrochloric acid until the red colour has vanished. The soda only is saturated at this stage, and each c.c. of the acid corresponds to 0.0062 g. Na_2O . Now add a single drop of methyl orange and continue the titration with the same acid, but at a temperature of 30° , until the alumina first precipitated has been redissolved and the red colour has appeared. Each c.c. of acid used in this second titration corresponds to 0.003107 g. Al_2O_3 . The percentage is obtained directly when employing 0.200 g. substance by multiplying the c.c. used in the first titration (a) by 3.105 = per cent. Na_2O , and those used in the second titration (b) by 1.704 = per cent. Al_2O_3 .

(b) *Insoluble matter* is estimated in 10 to 20 g. substance in the usual manner, but employing "hardened" filtering paper, since ordinary filter paper would not stand the strongly caustic solution.

(c) *Silica* is estimated by evaporating with hydrochloric acid, digesting the residue with dilute HCl, filtering, washing, igniting, and weighing the residue.

3. *Commercial Alumina* is either the hydrate or anhydrous. In this the *silica* occurring as an impurity is estimated as in 2 (c); *total soda* by igniting at a red heat, digesting with water, heating with normal HCl, and titrating back the excess of acid; *soluble soda* by boiling with 100 c.c. water and titration with normal HCl and phenolphthalein; *iron* in the hydrochloric acid solution as in No. 1 (b); *loss of weight on ignition* ($= \text{H}_2\text{O} + \text{CO}_2$) by heating for fifteen minutes over the blowpipe.

XVIII. CEMENT INDUSTRY.

A.---Portland Cement.

1. Raw Materials.

(a) *Limestone*. (a) Estimate *carbon dioxide*, as described p. 184, by titration or by volumetric estimation of CO_2 . It is calculated as CO_2 . In the presence of considerable quantities of magnesia (which is considered as an injurious constituent of cement), estimate it in the hydrochloric acid solution, as on p. 175, calculate it as MgCO_3 , and calculate the excess of CO_2 as CaCO_3 .

(b) *Argillaceous residue* is the difference between 100 and the carbonates found in (a). If there is much present, it may be examined like clay, No. (b).

(b) *Clay*.—The percentage of *coarse sand* (quartz) is found by elutriation. Weigh 50 g. of the *coarsely* ground, dried average sample into a rather large porcelain dish, pour over it 100 c.c. dilute hydrochloric acid (1 concentrated acid + 8 water), boil for about three hours, allow to cool, pour off the acid and direct a jet of water on to the mass, carefully rubbing it up with the fingers, so that only clay goes away with the water and pure sand remains behind. This plan is better than the application of mechanical elutriating apparatus.

The sand may be sorted by sieves into different sizes, viz., fine dust (down to 0.025 mm.), dust (0.040 mm.), fine sand (0.20 mm.), coarse sand (above this).

Complete analysis of clay (cf. *Tech. Meth.*, vol. i., p. 569, and pp. 688 *et seq.*).

1. *Decomposition by means of alkaline carbonate*, i.e., a mixture of equal parts potassium carbonate and sodium carbonate, of which 6 to 10 g. are required for one part of clay. Dry the clay at 120° , grind it very finely, mix it intimately with the alkaline carbonate in the platinum crucible itself by means of a platinum or glass spatula (which is afterwards cleaned with a little car-

bonate), and heat in the covered crucible, first slowly, then up to full, quiet fusion. A good Mecker or Fletcher burner is preferable to the blowpipe for the heating. After cooling, heat the bottom of the crucible by a small flame to a low red heat twice successively, in order to facilitate the separation of the fused mass, allow to cool, add a few c.c. of water, and heat gently with a small flame, until the cake detaches itself from the crucible. Wash it into a good-sized platinum dish, cover this with a large watch-glass and heat on the water-bath until the mass has softened and fallen to powder. Then add an excess of hydrochloric acid, remove the watch-glass, wash its under-surface, and evaporate to dryness on the water-bath. During the evaporation the mass is stirred with a glass rod, so as to render the residue powdery. Then heat the dish in an air-bath to 120° for an hour, moisten it, after cooling, with moderately strong hydrochloric acid, allow to stand for an hour, heat up with water, pour the clear portion through a filter, and continue this treatment until the residue ceases to yield a colour with hydrochloric acid. Then transfer it to a filter, wash, dry, and ignite it first over a small flame, then to constancy of weight, and weigh it as *silica*. It may still contain some *titanic acid*. This is separated by evaporating with hydrofluoric acid and concentrated sulphuric acid on the water-bath as a residue which should be tested whether it yields the purple microcosmic salt bead of TiO_2 .

The filtrate from the *titanic acid* is divided in two halves. In one of these estimate *alumina + ferric oxide* by adding pure ammonia (free from carbonate) in slight excess, boiling up for a moment, filtering, washing, and igniting. In the other half estimate the *iron* by reducing with zinc and titrating with permanganate.

In the filtrate from the precipitate of $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$, estimate *calcium* by precipitation with ammonium oxalate (p. 175), and in the filtrate from this *magnesium* by ammonium phosphate (p. 175).

2. *The Alkalies* can be estimated, if desired, by decomposing about 5 g. clay with hydrofluoric acid; cf. *Tech. Meth.*, vol. i., p. 694.

3. *Sulphur*, present as sulphates or pyrites, is estimated by oxidation with aqua regia and precipitating the hydrochloric acid solution with barium chloride; cf. p. 134.

4. *Carbon dioxide*, as in the case of limestone, p. 184.

5. *Loss of weight on ignition* over the blowpipe or a powerful gas burner gives water + organic matter + CO_2 + sulphur present as pyrites, etc.

(c) *Separation of Silica present as Quartz, and that present in the Form of Silicates*.—The separation of these two kinds of silica is frequently demanded in so-called "rational analysis of clay." It can be effected by the process of Lunge and Milberg (*Z. angew. Chem.*, 1897, p. 393), on the basis of the observation that extremely finely divided *quartz* is dissolved by concentrated

caustic soda solution, but not by a 5 per cent. solution of sodium carbonate, whilst the latter dissolves the silica, separated from *silicates* by strong acids in an *amorphous* state, when heated on the water-bath for half an hour. This is applied to the separation of the two modifications of silica as follows:—Heat 5 g. of clay (dried at 120°) with dilute sulphuric acid (50 c.c. concentrated acid + 100 c.c. water) to boiling in a porcelain or platinum dish, covered with a watch-glass, until the water has been driven off and fumes of SO_3 begin to escape, allow to cool, dilute with water, pour off the liquid, moisten the residue with hydrochloric acid, heat for a quarter of an hour, filter, and wash. Wash the moist residue, which contains a mixture of both modifications of SiO_2 , into a porcelain dish, make up the solution to about 250 c.c. add about 12.5 g. pure anhydrous sodium carbonate, and heat on the water-bath for half an hour. Then pour off the clear liquid and repeat the treatment with 5 per cent. solution of Na_2CO_3 three times. Finally, wash the insoluble matter on to a filter and wash it thoroughly with water containing a little alcohol. The dried and ignited residue consists of the SiO_2 present as quartz; the difference between this and the total SiO_2 found in (b) 1 is the SiO_2 present as silicates.

2. Control of the Working Conditions.

The *crude mixture* is tested for its percentage of clay and calcium carbonate like limestone; compare A, 1. Usually the estimation of CO_2 (p. 184) is sufficient.

The *clinker* is analysed like the finished cement, if this is required.

3 Commercial Cement.

Ignite 1 g. cement in a platinum crucible over the blowpipe for fifteen minutes, decompose by hydrochloric acid, filter from the insoluble matter, fuse this with sodium carbonate, dissolve the melt in water, and unite this solution with the filtrate previously obtained. In this solution the following estimations are made:—

(a) *Silica* is determined by boiling down the united solutions and filtering off the precipitated SiO_2 . The filtrate is again concentrated by boiling, and any SiO_2 that separates is united with the first portion. Dry the total (crude) silica, heat on the blowpipe for half an hour, and weigh. Then heat with 10 c.c. hydrofluoric acid and four drops concentrated sulphuric acid till fumes cease to be given off, and deduct the residue from the crude SiO_2 ; the portion thus removed by volatilisation represents the real SiO_2 .

(b) Divide the united filtrates into two halves. In one of these estimate the *Sesquioxides*, $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$, by precipitation with pure ammonia, as on p. 255.

(c) *Ferric oxide* is estimated in the second half of the filtrate from (a), by reducing to the ferrous state by means of zinc or H_2S and titrating with permanganate.

(d) *Calcium* is estimated in the filtrate obtained in (b) by precipitation with ammonium oxalate, p. 175.

(e) *Magnesium* in the filtrate from (d), by precipitation with ammonium phosphate, p. 175.

(f) *Sulphates* are determined in a special sample by dissolving 1 g. in hot hydrochloric acid, filtering, and precipitating with barium chloride, p. 134.

(g) *Total Sulphur*.—Fuse 1 g. cement with sodium carbonate and a little potassium nitrate, dissolve in hot water, filter, acidify, and precipitate with barium chloride.

(h) The estimation of *alkalies* is rather troublesome, and is only carried out in exceptional cases; cf. *Tech. Meth.* i., p. 694.

(i) The *physical tests* for *fineness of grinding, time of setting, breaking strain*, etc., are described *ibid.*

B.—Hydraulic Lime and Roman Cement.

The raw material for these are *marls*. In these usually only CO_2 and argillaceous residue are estimated, as in the case of limestone, p. 254.

An accurate analysis can be made as described for clay, p. 254, more especially the separation of the silica present as quartz from that of the silicates.

C. Puzzuolanas, Trass, Granulated Blast-Furnace Slag.

1. *Hygroscopic water* is estimated by drying 10 g. at 110° .

2. *Chemically combined Water*.—Ignite 1 g. of the substance dried as in No. 1 in a platinum crucible by means of the blowpipe, a Hempel gas-furnace, or other suitable means. The temperature ought to be raised gradually, so as to attain a red heat in about ten minutes, in order to avoid mechanical losses by dust being carried away through a sudden liberation of steam. After this continue the heating for half an hour to a yellow heat, and then transfer at once to the desiccator. The loss of weight is an important criterion for the hydraulicity.

3. *Silica present as silicates* should be estimated as well as that of quartz as an important hydraulic factor, as described p. 255.

4. *Mechanical tests* for fineness of grinding, etc., as for cement, *supra*, p. 254.

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